

Laparoscopic liver resection with selective prior vascular control

Hadrien Tranchart, M.D.^{a,c}, Giuseppe Di Giuro, M.D.^{a,c},
Panagiotis Lainas, M.D., Ph.D.^{a,c}, Guillaume Pourcher, M.D.^{a,c},
Niaz Devaquet, M.D.^{a,c}, Gabriel Perlemuter, M.D., Ph.D.^{b,c},
Dominique Franco, M.D., Ph.D.^{a,c}, Ibrahim Dagher, M.D., Ph.D.^{a,c,*}

^aDepartment of Minimally Invasive Digestive Surgery, Antoine-Béclère Hospital, Assistance Publique - Hôpitaux de Paris (AP-HP), Clamart, France; ^bDepartment of Gastroenterology, Antoine-Béclère Hospital, Assistance Publique - Hôpitaux de Paris (AP-HP), Clamart, France; ^cParis-Sud University, Orsay, France

KEYWORDS:

Hepatectomy;
Laparoscopy;
Liver;
Vascular control;
Anatomic

Abstract

BACKGROUND: Selective control of vascular inflow can reduce blood loss and transfusion rates and may be particularly efficient in laparoscopic liver resection (LLR). The aim of this study was to evaluate the efficacy of selective prior vascular control (PVC) in patients undergoing laparoscopic or open liver resections (OLR).

METHODS: Between 1999 and 2008, 52 patients underwent LLR with PVC with prospective data collection and were compared with patients undergoing OLR with PVC.

RESULTS: There was no difference in the operative time between the 2 groups. Blood loss and transfusion rates were lower in patients who underwent LLR (367 vs 589 mL, $P = .001$; 3.8% vs 17.3%, $P = .05$, respectively). Morbidity did not differ significantly between the 2 groups. Hospital stay was longer in the OLR group (11.0 vs 7.4 days, $P = .001$).

CONCLUSIONS: PVC during LLR was feasible and improved intraoperative and postoperative results. Selective PVC should be obtained in LLR whenever possible.

© 2013 Elsevier Inc. All rights reserved.

Blood loss during liver resections affects perioperative morbidity and mortality.¹ Perioperative blood transfusions are also associated with a higher rate of recurrence and lower survival after the resection of colorectal liver metastases² and hepatocellular carcinoma.³ The following surgical procedures can decrease blood loss and the need for transfusion considerably: the use of low central venous

pressure,⁴ new hemostatic devices for parenchymal transection,^{5,6} and the control of vascular inflow^{5,7} and outflow⁸ before liver division. Clamping of the hepatic pedicle (the Pringle maneuver) may induce ischemic lesions in the future remnant liver, particularly in cases of underlying liver disease.^{9,10} Such ischemic lesions may be prevented to some extent by intermittent portal triad clamping¹¹ or liver ischemic preconditioning.¹² Selective hemihepatic vascular occlusion of the liver results in similar blood loss and transfusion requirements to clamping of the total portal pedicle.¹³ Furthermore, selective clamping causes no ischemic injury in the remnant liver and may be particularly useful in laparoscopy because of the longer duration

* Corresponding author. Tel.: +33-(0)1-4537-4545; fax: +33-(0)1-4537-4978.

E-mail address: ibrahim.dagher@abc.aphp.fr

Manuscript received November 14, 2011; revised manuscript January 23, 2012

of parenchymal transection. The clamping of the portal pedicle for longer periods may induce larger ischemic liver lesions.

In laparoscopy, selective vascular control is facilitated by image magnification, allowing a very precise dissection of the portal pedicle, sectorial, and even segmental branches. The positive pressure of the pneumoperitoneum may also play an additional hemostatic role. Thus, laparoscopic liver resection (LLR) with inflow vascular ligation before transection may be associated with lower levels of blood loss than laparotomy. The aim of this retrospective comparative study was to evaluate the efficacy of selective prior vascular control (PVC) in patients undergoing laparoscopic or open liver resections.

Methods

Between 1999 and 2008, 52 patients underwent LLR with PVC (right hepatectomy in 50%, left hepatectomy in 3.8%, and left lateral sectionectomy in 46.2%). Segmental and nonanatomic resections were performed without PVC (Table 1). The selection criteria for laparoscopic resection were tumors well clear from the portal pedicle or hepatic veins, an American Society of Anesthesiologists score less than or equal to 3, compensated cirrhosis or noncirrhotic liver, esophageal varices less than or equal to 1, and a platelet count greater than or equal to $80 \times 10^9/L$. We compared patients undergoing laparoscopy with PVC with patients undergoing open surgery with PVC selected from our liver resection database. The patients from the laparoscopy and open groups were matched for sex, age, American Society of Anesthesiologists score, type of liver resection, presence and severity of liver disease, and tumor size.

Operative and perioperative management

Surgical technique, postoperative care, clinical data collection, and histologic analysis were performed as

previously described.^{14–17} Our surgical technique is similar for open liver resection and LLR, particularly for anatomic liver resections. Indeed, in anatomic resections, portal vessels and hepatic veins were controlled and divided before parenchymal transection. In right hepatectomy, the right sectorial branch of the portal vein and the right branch of the hepatic artery were dissected outside the liver parenchyma and divided.¹⁸ For left hepatectomy, the left portal branch and the left branch of the hepatic artery were also controlled extraparenchymally and divided (Fig. 1). Left lateral sectionectomies were performed with prior control of the portal pedicle for segments II and III separately. The hepatic vein concerned was also controlled before parenchymal transection.

For LLR, we used an entirely laparoscopic technique with 5 ports, a 10- to 12-mm Hg pneumoperitoneum, a 0° laparoscope, and a robotic camera holder. Parenchymal transection was performed by ultrasound dissection (Ultracision; Ethicon, Issy les Moulineaux, France) or thermofusion (Ligasure; Covidien, Elancourt, France). Bipolar coagulation was used to treat minor bleeding.

Study criteria

The surgical variables evaluated were the duration of the intervention, blood loss, transfusion rate, conversion rate, and resection margin. The postoperative variables assessed were specific and overall morbidity, perioperative mortality, and length of hospital stay. Postoperative complications were classified as specific liver-related complications (ie, cirrhotic decompensation, hemorrhage, or biliary collection) and general complications. Complication severity was stratified according to the modified Clavien classification.¹⁹

Statistical analysis

Matching and statistical analyses were performed with NCSS 2007 software (NCSS, LLC, Kaysville, UT). Continuous variables were expressed as means $\pm$ standard deviation and were compared by using the Mann-Whitney *U* test. The Fisher exact test was used for comparisons of categorical variables. Values of $P < .05$ were considered statistically significant.

Results

Demographic parameters

Fifty-two patients underwent laparoscopic liver resection with PVC and were compared in a case-match analysis with 52 patients retrospectively selected from our open surgery database. The 2 groups of patients were also similar in terms of body mass index, preoperative liver blood test results, and histologic type of resected tumor (benign/malignant) (Table 2).

Table 1 Types of liver resection for patients undergoing laparoscopic hepatectomy with and without PVC

	With PVC (n = 52)	Without PVC (n = 36)
Right hepatectomy, n (%)	26 (50.0)	0
Left hepatectomy, n (%)	2 (3.8)	0
Left lateral sectionectomy, n (%)	24 (46.2)	0
Trisegmentectomy V-VI-VII, n (%)	0	1 (2.8)
Bisegmentectomy V-VI, n (%)	0	2 (5.5)
Segmentectomy, n (%)	0	12 (33.3)
Segmentectomy I, n (%)	0	2 (5.5)
Segmentectomy IV, n (%)	0	1 (2.8)
Segmentectomy V, n (%)	0	7 (19.5)
Segmentectomy VI, n (%)	0	2 (5.5)
Atypical, n (%)	0	21 (58.4)

PVC = prior vascular control.

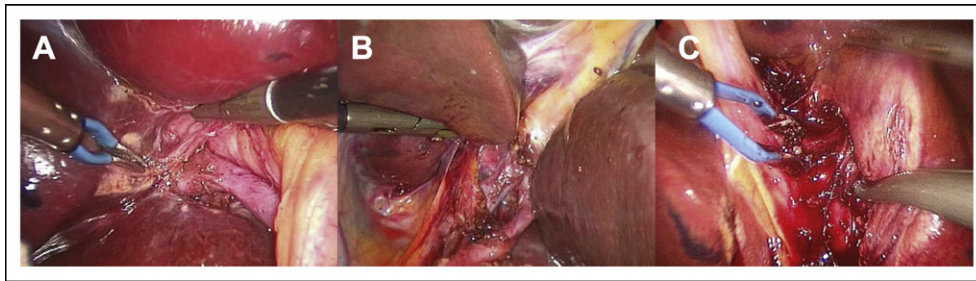


Figure 1 (A) Control of the right portal branch. (B) Control of the left portal branch. (C) Control of the portal pedicle for segment III.

Surgical results

There was no difference in the operative time between the 2 groups (309 minutes for laparoscopy vs 295 minutes for laparotomy, $P = .75$, Table 3). The Pringle maneuver was used in 40% of patients in the open surgery group and in none of those undergoing laparoscopy. However, blood loss and transfusion rates were lower in the laparoscopy group (367 mL vs 589 mL, $P = .001$; transfusions: 3.8% vs 17.3%, $P = .05$, respectively). There was no difference in surgical margin between the 2 groups ($P = .80$).

Postoperative results

Specific and general morbidity did not differ significantly between the 2 groups (specific: 1.9% vs 11.5% in the laparoscopy and laparotomy groups, respectively, $P = .11$;

general: 13.3% vs 13.3% in the laparoscopy and laparotomy groups, respectively, $P = 1.00$, Table 4). However, all the cases of ascites were observed in the open surgery group (11.5%) with no such cases identified in the laparoscopy group ($P = .02$). One cirrhotic patient in the laparotomy group died from postsurgical liver failure 40 days after surgery. Hospital stay was longer in the open surgery group (11 vs 7.4 days, $P = .001$).

Comments

Various procedures have been described for decreasing blood loss and the need for perioperative transfusions, which are associated with perioperative morbidity, mortality, and poor survival.¹⁻³ Selective PVC has been shown to decrease bleeding or transfusion requirements efficiently, particularly in patients with pathological parenchyma.⁹ In

Table 2 Demographic characteristics of patients undergoing laparoscopic and open hepatectomy with PVC and characteristics of their tumors and livers

	Laparoscopy group (n = 52)	Open group (n = 52)	P value
Patients			
Sex (F/M)	23/29	23/29	1.00
Age (y) $\pm$ SD	59.8 $\pm$ 13.3	59.6 $\pm$ 12.6	.85
BMI (kg/m ²) $\pm$ SD	25.3 $\pm$ 3.5	25.7 $\pm$ 3.5	.98
ASA (1/2/3)	20/26/6	20/26/6	1.00
Types of liver resection			
Right hepatectomy, n (%)	26 (50)	26 (50)	1.00
Left hepatectomy, n (%)	2 (3.8)	2 (3.8)	1.00
Left lateral sectionectomy, n (%)	24 (46.2)	24 (46.2)	1.00
Underlying liver			
Normal, n (%)	34 (65.4)	34 (65.4)	1.00
Pathologic, n (%)	18 (34.6)	18 (34.6)	1.00
Cirrhosis, n (%)	10 (19.2)	10 (19.2)	1.00
AST (IU/L) $\pm$ SD	37.4 $\pm$ 40.1	35.3 $\pm$ 27.7	.78
ALT (IU/L) $\pm$ SD	29.0 $\pm$ 18.7	34.7 $\pm$ 24.4	.37
PT (%) $\pm$ SD	89.5 $\pm$ 10.1	92.4 $\pm$ 8.1	.47
Total bilirubin (μ mol/L) $\pm$ SD	10.4 $\pm$ 6.9	13.1 $\pm$ 9.8	.10
Tumor characteristics			
Tumor size (mm) $\pm$ SD	50.2 $\pm$ 24.3	51.6 $\pm$ 23.6	.72
Benign/malignant, n	19/33	19/33	1.00

Total bilirubin, normal value: 2–17 μ mol/L.

ALT = alanine aminotransferase (normal value, 11–60 IU/L); ASA = American Society of Anesthesiologists physical status score; AST = aspartate aminotransferase (normal value, 14–50 IU/L); BMI = body mass index; F = female; M = male; PT = prothrombin time; PVC = prior vascular control; SD = standard deviation.

Table 3 Surgical results for patients undergoing laparoscopic and open hepatectomy with PVC

	Laparoscopy group (n = 52)	Open group (n = 52)	P value
Duration of surgery (min) $\pm$ SD	309.2 $\pm$ 114.3	295.5 $\pm$ 87.2	.75
Blood loss (mL) $\pm$ SD	367.3 $\pm$ 484.3	589.8 $\pm$ 428.1	.001
Transfusion, n (%)	2 (3.8)	9 (17.3)	.05
Packed red blood cell units $\pm$ SD	3.0 $\pm$.0	5.1 $\pm$ 1.1	—
Use of portal triad clamping, n (%)	0 (0)	21 (40.3)	<.0001
Duration of portal triad clamping (min) $\pm$ SD	—	30.6 $\pm$ 12.9*	—
Surgical margin (mm) $\pm$ SD	14.3 $\pm$ 12.1	14.8 $\pm$ 16.0	.80

PVC = prior vascular control. SD = standard deviation.

*Data for the 21 patients who underwent portal triad clamping.

this study, we showed the feasibility of PVC during LLR and the greater efficacy of this approach in laparoscopy compared with open surgery.

Laparoscopic liver surgery is now recognized as a safe procedure with better surgical and postoperative outcomes compared with laparotomy for minor liver resections.²⁰ Successful laparoscopic major resections have been reported recently by expert teams in hepatic surgery and laparoscopy.^{16,18,21–24} We have previously shown the efficacy of PVC during laparoscopic right hepatectomy.¹⁶ In this series, PVC during LLR was possible in most anatomic left and right hepatectomies and in left lateral sectionectomies. We also believe that the magnification achieved with laparoscopy allows precise dissection of the portal pedicles, facilitating their extraparenchymal control. In addition, the position of the laparoscope (ie, parallel to the vena cava) provides an excellent view of the retrohepatic space and the hepatocaval confluence.

Blood loss and transfusion rates were significantly lower in patients undergoing laparoscopy than in those undergoing laparotomy. Previous comparative studies have reported lower levels of blood loss during laparoscopy but did not identify significant differences in the transfusion rate.^{25–31} Most of these studies involved nonanatomic resections or anatomic resections without PVC. The superiority of new

hemostatic devices for parenchymal transection developed specifically for LLR over the conventional clamp crushing method⁶ has yet to be shown. Therefore, we suggest that during LLR bleeding is essentially controlled by the PVC; this effect is strengthened by the pneumoperitoneum, which may play an additional hemostatic role. Indeed, the vascular pressure along the liver stump is related to the inflow (decreased by PVC), the outflow (decreased by low central venous pressure), and the counter pressure of pneumoperitoneum. Positive-pressure pneumoperitoneum has been shown to decrease blood loss caused by liver trauma in an animal model.³² The intra-abdominal pressure used in our LLR was about 10 to 12 mm Hg and could be increased to 15 mm Hg in cases of more serious bleeding of the liver stump. The use of low CVP during laparoscopy is associated with a theoretic increase in the risk of carbon dioxide embolism at insufflation pressures exceeding the CVP, causing a pressure gradient in the venous circulation.³³ The impact of pneumoperitoneum is well known, and the possibility of adverse effects, particularly in high-risk patients, has been ruled out.³⁴ Carbon dioxide embolism frequently occurs during LLR.³⁵ In an animal model, this was found to have minimal clinical effects.³⁶

Two comparative studies have focused on the duration of portal triad clamping, which they showed to be longer in

Table 4 Postoperative results for patients undergoing laparoscopic and open hepatectomy with PVC

	Laparoscopy group (n = 52)	Open group (n = 52)	P value
Specific morbidity, n (%)	1 (1.9)	6 (11.5)	.11
Hemorrhage	0	0	—
Cirrhotic decompensation	0	6 (11.5)	.02
Biliary collection	1 (1.9)	0	1.00
General morbidity, n (%)	7 (13.3)	7 (13.3)	1.00
Pulmonary	0	3 (5.7)	.24
Parietal	2 (3.8)	2 (3.8)	1.00
Urinary	2 (3.8)	0	.49
Cardiovascular	0	2 (3.8)	.49
Other	3 (5.7)	0	.24
Mortality (%)	0	1 (1.9)	1.00
Severity of complications according to Clavien classification			
Grade I, II, III, IV, V	3, 3, 2, 0, 0	3, 5, 5, 0, 1	—
Hospital stay (d)	7.4 $\pm$ 5.9	11.0 $\pm$ 8.9	.001

PVC = prior vascular control.

Table 5 Demographic characteristics of patients undergoing laparoscopic hepatectomy with and without PVC and characteristics of their tumors and livers

	With PVC (n = 52)	Without PVC (n = 36)	P value
Patients			
Sex (F/M)	23/29	17/19	.83
Mean age (y) $\pm$ SD	59.8 $\pm$ 13.3	55.9 $\pm$ 14.8	.29
BMI (kg/m ²) $\pm$ SD	25.3 $\pm$ 3.5	27.4 $\pm$ 4.6	.19
ASA (1/2/3)	20/26/6	11/20/5	.74
Underlying liver			
Normal, n (%)	34 (65.4)	21 (58.3)	.51
Pathologic, n (%)	18 (34.6)	8 (22.2)	.24
Cirrhosis, n (%)	10 (19.2)	7 (19.4)	1.00
AST (IU/L) $\pm$ SD	37.4 $\pm$ 40.1	44.0 $\pm$ 23.6	.07
ALT (IU/L) $\pm$ SD	29.0 $\pm$ 18.7	40.5 $\pm$ 17.9	.07
PT (%) $\pm$ SD	89.5 $\pm$ 10.1	86.3 $\pm$ 12.4	.67
Total bilirubin (μ mol/L) $\pm$ SD	10.4 $\pm$ 6.9	11.6 $\pm$ 5.7	.96
Tumor characteristics			
Tumor size (mm) $\pm$ SD	50.2 $\pm$ 24.3	42.3 $\pm$ 28.7	.05
Benign/malignant, n	19/33	16/20	.51

Total bilirubin, normal value: 2–17 μ mol/L.

ALT = alanine aminotransferase (normal value, 11–60 IU/L); ASA = American Society of Anesthesiologists physical status score; AST = aspartate aminotransferase (normal value, 14–50 IU/L); BMI = body mass index; F = female; M = male; PT = prothrombin time; PVC = prior vascular control; SD = standard deviation.

laparoscopy.^{29,31} The Pringle maneuver during LLR may lead to significant cardiovascular changes, particularly in patients with preexisting cardiac disease.³⁷ Furthermore, it has been shown recently in a swine model that portal triad clamping during laparoscopy associated with an increase in intraperitoneal pressure may alter hepatic vein reverse circulation, inducing more severe hepatic ischemia than the pedicle clamping performed in laparotomy.³⁸ These findings support our conclusion that selective PVC is more

suitable than complete portal clamping for laparoscopic liver resection.

We also performed a second analysis in which we compared LLR with PVC with LLR without PVC. Based on our experience with LLR, we performed all laparoscopic left lateral sectionectomies and major LLR with PVC (Table 1). Although LLR without PVC included only segmental and nonanatomic resections, no statistical difference in blood loss or the transfusion rate was observed between the

Table 6 Surgical and postoperative results for patients undergoing laparoscopic hepatectomy with and without PVC

	With PVC (n = 52)	Without PVC (n = 36)	P value
Duration of surgery (min) $\pm$ SD	309.2 $\pm$ 114.3	197.0 $\pm$ 114.2	<.0001
Blood loss (mL) $\pm$ SD	367.3 $\pm$ 484.3	348.5 $\pm$ 437.2	.76
Conversion, n (%)	1 (1.9)	2 (5.5)	.56
Transfusion, n (%)	2 (3.8)	5 (13.8)	.12
Packed red blood cell units $\pm$ SD	3.0 $\pm$.0	3.4 $\pm$ 1.1	—
Surgical margin (mm) $\pm$ SD	14.3 $\pm$ 12.1	9.8 $\pm$ 8.0	.52
Specific morbidity, n (%)	1 (1.9)	3 (8.3)	.30
Hemorrhage	0	0	—
Cirrhotic decompensation	0	2 (5.5)	.16
Biliary collection	1 (1.9)	1 (2.8)	1.00
General morbidity, n (%)	7 (13.3)	3 (8.3)	.52
Pulmonary	0	0	—
Parietal	2 (3.8)	1 (2.8)	1.00
Urinary	2 (3.8)	0	.51
Cardiovascular	0	2 (5.5)	.16
Other	3 (5.7)	0	.27
Severity of complications according to Clavien classification			
Grade I, II, III, IV, V	3, 3, 2, 0, 0	0, 4, 2, 0, 0	—
Mortality (%)	0	0	—
Hospital stay (d) $\pm$ SD	7.4 $\pm$ 5.9	5.5 $\pm$ 6.8	<.0006

PVC = prior vascular control; SD = standard deviation.

2 groups. This may be explained by the fact that in left lateral sectionectomies and left or right hepatectomies, liver transection is performed through an anterior-posterior approach, facilitating division through the direct control of the various vessels, which are always encountered in a horizontal plane. In segmental and nonanatomic resections, liver division is performed in different planes, making it harder to expose the liver stump. Small anterior tumors treated by segmental and nonanatomic resections may appear to be more suitable for LLR, but they may actually be the most demanding. In our view, formal anatomic resections, typically left lateral sectionectomies, are the best procedures for inexperienced surgeons wishing to begin performing LLR. In addition, we found no difference between the 2 groups in terms of the surgical margin despite the fact that larger tumors were included in the PVC group (Table 5). Surgery was longer in the PVC group, partly because of an additional vascular dissection step, but this also reflects the inclusion in this group of all the major resections. Furthermore, the conversion rate and postoperative outcome (except hospital stay) were not significantly different between the 2 groups (Table 6).

The magnification of laparoscopy allows a very precise dissection of portal pedicles and hepatic veins and makes PVC feasible and safe. Our data suggest that PVC is more effective in LLR than in open surgery. These results should encourage experienced liver surgeons to expand the use of laparoscopy in anatomic liver resections, even major hepatectomies.

References

- Jarnagin WR, Gonen M, Fong Y, et al. Improvement in perioperative outcome after hepatic resection: analysis of 1,803 consecutive cases over the past decade. *Ann Surg* 2002;236:397–406.
- Stephenson KR, Steinberg SM, Hughes KS, et al. Perioperative blood transfusions are associated with decreased time to recurrence and decreased survival after resection of colorectal liver metastases. *Ann Surg* 1988;208:679–87.
- Katz SC, Shia J, Liao KH, et al. Operative blood loss independently predicts recurrence and survival after resection of hepatocellular carcinoma. *Ann Surg* 2009;249:617–23.
- Melendez JA, Arslan V, Fischer ME, et al. Perioperative outcomes of major hepatic resections under low central venous pressure anesthesia: blood loss, blood transfusion, and the risk of postoperative renal dysfunction. *J Am Coll Surg* 1998;187:620–5.
- Lesurtel M, Selzner M, Petrowsky H, et al. How should transection of the liver be performed?: a prospective randomized study in 100 consecutive patients: comparing four different transection strategies. *Ann Surg* 2005;242:814–22.
- Ikeda M, Hasegawa K, Sano K, et al. The vessel sealing system (LigaSure) in hepatic resection: a randomized controlled trial. *Ann Surg* 2009;250:199–203.
- Pringle JH. V. Notes on the arrest of hepatic hemorrhage due to trauma. *Ann Surg* 1908;48:541–9.
- Smyrniotis V, Kostopanagiotou G, Lolis E, et al. Effects of hepatovenous back flow on ischemic-reperfusion injuries in liver resections with the pringle maneuver. *J Am Coll Surg* 2003;197:949–54.
- Makuuchi M, Mori T, Gunven P, et al. Safety of hemihepatic vascular occlusion during resection of the liver. *Surg Gynecol Obstet* 1987;164:155–8.
- Huguet C, Gavelli A, Bona S. Hepatic resection with ischemia of the liver exceeding one hour. *J Am Coll Surg* 1994;178:454–8.
- Belghiti J, Noun R, Malafosse R, et al. Continuous versus intermittent portal triad clamping for liver resection: a controlled study. *Ann Surg* 1999;229:369–75.
- Clavien PA, Selzner M, Rudiger HA, et al. A prospective randomized study in 100 consecutive patients undergoing major liver resection with versus without ischemic preconditioning. *Ann Surg* 2003;238:843–50.
- Figuera J, Llado L, Ruiz D, et al. Complete versus selective portal triad clamping for minor liver resections: a prospective randomized trial. *Ann Surg* 2005;241:582–90.
- Dagher I, Belli G, Fantini C, et al. Laparoscopic hepatectomy for hepatocellular carcinoma: a European experience. *J Am Coll Surg* 2010;211:16–23.
- Tranchart H, Di Giuro G, Lainas P, et al. Laparoscopic resection for hepatocellular carcinoma: a matched-pair comparative study. *Surg Endosc* 2010;24:1170–6.
- Dagher I, Di Giuro G, Dubrez J, et al. Laparoscopic versus open right hepatectomy: a comparative study. *Am J Surg* 2009;198:173–7.
- Di Giuro G, Lainas P, Franco D, et al. Laparoscopic left hepatectomy with prior vascular control. *Surg Endosc* 2010;24:697–9.
- Dagher I, Caillard C, Proske JM, et al. Laparoscopic right hepatectomy: original technique and results. *J Am Coll Surg* 2008;206:756–60.
- Dindo D, Demartines N, Clavien PA. Classification of surgical complications: a new proposal with evaluation in a cohort of 6336 patients and results of a survey. *Ann Surg* 2004;240:205–13.
- Nguyen KT, Marsh JW, Tsung A, et al. Comparative benefits of laparoscopic vs open hepatic resection: a critical appraisal. *Arch Surg* 2011;146:348–56.
- Gayet B, Cavaliere D, Vibert E, et al. Totally laparoscopic right hepatectomy. *Am J Surg* 2007;194:685–9.
- Chang S, Laurent A, Tayar C, et al. Laparoscopy as a routine approach for left lateral sectionectomy. *Br J Surg* 2007;94:58–63.
- Tranchart H, Diop PS, Lainas P, et al. Laparoscopic major hepatectomy can be safely performed with colorectal surgery for synchronous colorectal liver metastasis. *HPB (Oxford)* 2011;13:46–50.
- Dagher I, O'Rourke N, Geller DA, et al. Laparoscopic major hepatectomy: an evolution in standard of care. *Ann Surg* 2009;250:856–60.
- Morino M, Morra I, Rosso E, et al. Laparoscopic vs open hepatic resection: a comparative study. *Surg Endosc* 2003;17:1914–8.
- Rau HG, Buttler E, Meyer G, et al. Laparoscopic liver resection compared with conventional partial hepatectomy—a prospective analysis. *Hepatogastroenterology* 1998;45:2333–8.
- Mala T, Edwin B, Gladhaug I, et al. A comparative study of the short-term outcome following open and laparoscopic liver resection of colorectal metastases. *Surg Endosc* 2002;16:1059–63.
- Farges O, Jagot P, Kistetter P, et al. Prospective assessment of the safety and benefit of laparoscopic liver resections. *J Hepatobiliary Pancreat Surg* 2002;9:242–8.
- Laurent A, Cherqui D, Lesurtel M, et al. Laparoscopic liver resection for subcapsular hepatocellular carcinoma complicating chronic liver disease. *Arch Surg* 2003;138:763–9.
- Kaneko H, Takagi S, Otsuka Y, et al. Laparoscopic liver resection of hepatocellular carcinoma. *Am J Surg* 2005;189:190–4.
- Lesurtel M, Cherqui D, Laurent A, et al. Laparoscopic versus open left lateral hepatic lobectomy: a case-control study. *J Am Coll Surg* 2003;196:236–42.
- Jaskille A, Schechner A, Park K, et al. Abdominal insufflation decreases blood loss and mortality after porcine liver injury. *J Trauma* 2005;59:1305–8.
- Bazin JE, Gillart T, Rasson P, et al. Haemodynamic conditions enhancing gas embolism after venous injury during laparoscopy: a study in pigs. *Br J Anaesth* 1997;78:570–5.
- Poon JT, Law WL, Chow LC, et al. Outcome of laparoscopic resection for colorectal cancer in patients with high operative risk. *Ann Surg Oncol* 2011;18:1884–90.

35. Schmandra TC, Mierdl S, Hollander D, et al. Risk of gas embolism in hand-assisted versus total laparoscopic hepatic resection. *Surg Technol Int* 2004;12:137–43.
36. Jayaraman S, Khakhar A, Yang H, et al. The association between central venous pressure, pneumoperitoneum, and venous carbon dioxide embolism in laparoscopic hepatectomy. *Surg Endosc* 2009;23:2369–73.
37. Decailliot F, Streich B, Heurtematte Y, et al. Hemodynamic effects of portal triad clamping with and without pneumoperitoneum: an echocardiographic study. *Anesth Analg* 2005;100:617–22.
38. Nsadi B, Gilson N, Pire E, et al. Consequences of pneumoperitoneum on liver ischemia during laparoscopic portal triad clamping in a swine model. *J Surg Res* 2011;166:e35–43.