J Hepatobiliary Pancreat Surg (2008) 15:596–602
DOI 10.1007/s00534-007-1326-2

Journal of HBP Surgery

Assessment of liver function for successful hepatectomy in patients with hepatocellular carcinoma with impaired hepatic function

Kazuhisa Uchiyama, Kazunari Mori, Katsuyoshi Tabuse, Masaki Ueno, Satoru Ozawa, Takayuki Nakase, Manabu Kawai, Masaji Tani, Hiroshi Tanimura, and Hiroki Yamaue

Second Department of Surgery, Wakayama Medical University, School of Medicine, 811-1 Kimiidera, Wakayama 641-8510, Japan

Abstract

Background/Purpose. This study aimed to construct a formula for assessing liver function in order to prevent post-hepatectomy liver failure.

Methods. A formula was constructed by analyzing data from 28 patients with hepatocellular carcinoma (HCC) with liver cirrhosis operated on between 1981 and 1984. Next, we evaluated the validity of this formula in 207 hepatectomy patients operated on from 1985 to 1999. For 145 hepatectomy patients operated on from 2000 to 2006, this formula was calculated before surgery in order to assess their risk of hepatectomy.

Results. The formula for liver functional evaluation, constructed from preoperative hepatic function parameters, was: liver failure score = 164.8 − 0.58 × Alb − 1.07 × HPT + 0.062 × GOT − 685 × K. ICG − 3.57 × OGTT. LI + 0.074 × RW, where Alb is albumin (g/dl); HPT, hepaplastin test (%); GOT, glutamate oxaloacetate transaminase (U/l); K. ICG, K value of indocyanine green clearance test; OGTT. LI, 60-min/120-min glucose level in 75-g oral glucose tolerance test. linearity index of OGTT; and RW, weight of resected liver (g). We decided that a score below 25 would be safe for hepatectomy.

Conclusions. The mortality rate decreased from 3.9% in 1985–1999 to 1.3% in 2000–2006. This finding allows us to conclude that the formula is valid for assessing the risk of post-hepatectomy liver failure.

Key words Hepatocellular carcinoma · Postoperative liver function · Assessment of liver function · Mortality rate

Introduction

Most livers with hepatic carcinomas are cirrhotic, and postoperative recovery of the liver weight cannot be expected after an extended hepatectomy, thus resulting in a state of liver failure. Since general hepatectomy was established for the treatment of hepatic carcinomas in 1980, it has become necessary to establish methods to assess the liver reserve capacity in order to avoid post-hepatectomy liver failure. Several institutions have reported liver reserve capacity assessment methods.[1–10] In addition to the Child-Pugh classification,[1] many reports have demonstrated methods for evaluating the liver reserve, incuding the indocyanine green retention value (ICG-R15),[2] ICG clearance test (ICG-K),[3] hippuric acid test (hippurate ratio),[4] lidocaine monoethylglycinexylidide (MEGX) test,[5] aminopyrine breath test,[6] and ^{99m}Tc-galactosylhuman serum albumin (GSA) scintigraphy.[7,8] Blood tests, such as hyaluronic acid, type IV collagen 7s, and type III procollagen-N-peptide (P-III-P) have also been used as markers of hepatic fibrosis due to cirrhosis.[9] Moreover, because the platelet count sensitively reflects the degree of hepatic fibrosis, and because ICR-R15 is a simple test, these two parameters have been considered useful as preoperative hepatic function evaluation factors, and they have been reported to be excellent predictors of postoperative death.[10] However, there are few reports with an accurate evaluation formula using multiple parameters.

From 1981 to 1984, we used the data of patients who underwent hepatectomy for hepatocellular carcinoma to construct an original liver function risk evaluation formula. This formula was applied over the next 15 years, and the accuracy of this formula and the surgical scores were validated in terms of liver failure risk. We then decided to select patients according to the scores in this formula, to determine whether or not hepatectomy should be performed in the patients.

Patients and methods

First, a liver failure risk evaluation formula was constructed by analyzing data from 28 HCC patients with

Offprint requests to: H. Yamaue
Received: October 19, 2007 / Accepted: November 27, 2007

liver cirrhosis whose serum albumin was below 3.5 g/dl and ICG K value was below 0.11. These patients underwent hepatectomy at Wakayama Medical University Hospital (WMUH) between 1981 and 1984. The 28 patients (male-to-female ratio of 27: 1) ranged from 36 to 73 years of age (mean, 55.7 years); 85.7% were positive for preoperative α-fetoprotein ($\geq$20 ng/µl), and all were complicated with cirrhosis. The surgical modalities were: right hepatectomy in 2 patients, left hepatectomy in 1, lateral segmentectomy in 5, anterior segmentectomy in 1, subsegmentectomy in 4, and partial resection in 15. Cholecystectomy was performed simultaneously with the hepatectomy in all patients. In the early period, as we did not have good enough technology or standard criteria for the hepatectomy, we lost 4 patients with postoperative liver failure. However, we were able to construct a formula whose scores may contribute to the achievement of safe resection in HCC patients with compromised hepatic function.

Next, between 1985 and 1999, validation of the liver failure risk evaluation formula was conducted in 207 patients with preoperative hepatic dysfunction or liver resection risk. Finally, for 145 hepatectomy patients operated on from 2000 to 2006, this formula was used to calculate the liver failure scores before surgery and to assess their risk of hepatectomy. Patients requiring biliary tract drainage, patients with diabetes who could not undergo an oral glucose tolerance test (OGTT), and patients in whom hospital death occurred due to other diseases, such as myocardial infarction or cerebral hemorrhage, were excluded from the study.

Five preoperative tests with different characteristics were selected to construct the evaluation formula: albumin level (g/dl), indicating the general nutrition status; hepaplastin test (%), a potent liver functional examination indicating the protein synthesis capacity of the liver; glutamate oxaloacetate transaminase (GOT; U/l), indicating the status of active hepatitis; K value of the ICG clearance, related to hepatic blood flow; and the linearity index of OGTT (OGTT. LI), which is related to the mitochondrial activity of hepatocytes. Then six parameters — the above five plus the weight of the resected liver, excluding the tumor weight (g) — were used as independent variables, and the liver failure score (score) was used as a dependent variable in a multiple regression analysis to find the regression formula. The analysis was performed using the *Statistics and calculation software library: multivariate analysis program* (Microsystems, Tokyo, Japan 1984). In the multivariate analysis, patients with intractable ascites (diuretics not effective for more than 1 month) and those with prolonged jaundice (serum bilirubin level more than 3 g/dl continuing for more than 1 month) after operation and those with hospital death were assigned a score of 100; while patients without any postoperative complications were assigned a score of 0.

The ICG clearance test was conducted by intravenous injection of the ICG reagent at a dose of 0.5 mg/kg body weight, and by collecting blood at 0, 5, 10, and 15 min to find the blood clearance rate (K value). The OGTT. LI was calculated from the ratio of the 60-min blood glucose to the 120-min blood glucose level in the peripheral blood after the 75-g OGTT (Trelan-G; Takeda Drug, Japan, Tokyo). Hepaplastin test, albumin, and GOT were measured at the Central Laboratories of WMUH. The resected liver weight, excluding the tumor weight, was determined by assuming the tumor to be spherical, and was calculated by subtracting the volume of a sphere having the greatest diameter of the tumor from the actual weight of the resected liver.

For the 207 patients operated on from 1985 to 1999 used in the validation, the data of the five preoperative tests and the resected liver weight, excluding the tumor volume, were substituted into the dependent variables of the liver function evaluation formula, and the score was then calculated for each patient. Next, the scores were compared with the actual postoperative outcomes in order to find the score at which death from liver failure occurred. Since 2000, the use of multidetector row computed tomography (MD-CT; AZE, Tokyo, Japan) has allowed for a three-dimensional image construction of the liver and also a preoperative estimation of the resected liver weight using software.[11] For the 145 hepatectomy patients with HCC operated on from 2000 to 2006, the liver function evaluation formula was used to calculate the liver failure scores before surgery in all of the patients, and their risk of hepatectomy was assessed.

In the present series, there were no cases of biliary reconstruction, portal vein tumor thrombectomy, or combined resection of the diaphragm or inferior vena cava (IVC). In brief, our operative procedures were as follows. After an ultrasonographic study, the gallbladder was removed and the liver was mobilized. Resection of the liver parenchyma was performed using an ultrasonic dissector, with intermittent clamping by means of the occlusion of blood inflow, eitther pedicular or selective, for 20 min and then release for 5 min, using a rubber tape with a tourniquet. In the present series, all hepatectomies were performed by five surgeons (K. U., K. M., K. T., H. T., and H. Y).

Data values are presented as means ± SD. For statistical analyses, Student's paired *t*-tests were used to evaluate differences in surgical parameters between patients grouped according to the formula scores (group A, score <25; group B, score 25–50; and group C, score $\geq$50), employing the StatView program (version 5; Hulinks, Tokyo, Japan). Statistical significance was defined as a P value of <0.05.

Results

From the multiple linear regression analysis, the following formula was obtained: liver function score = 164.8 − 0.58 × Alb − 1.07 × HPT + 0.062 × GOT − 685 × K. ICG − 3.57 × OGTT. LI + 0.074 × RW, where Alb is albumin (g/dl); HPT, hepaplastin test (%); GOT, (U/l); KICG, K, value of indocyanine green clearance test; OGTT. LI, 60-min/120-min glucose level in 75-g OGTT; and RW, weight of resected liver (g).

Table 1 shows a comparison of the patients' characteristics (age, sex, underlying liver disease, and Child-Pugh classification) for the 28 patients used as the sample for establishing the liver function risk evaluation formula (1981–1984; period A), the 207 patients used for the evaluation of this formula (1985–1999; period B), and the 145 patients who underwent hepatectomy with prior calculation of this formula (2000–2006; period C). The operative methods for patients in the three periods are shown in Table 2. The results for the aforementioned five preoperative liver function tests and the resected liver weight in these patients are shown in Table 3 (as means ± SD and ranges). In the liver functional tests of serum albumin level, hepaplastin test, and ICG K value, there were significant differences between period A and period B and between period A and period C. Each *P* value is shown in Table 3. There were no significant differences in the liver function test results between period B and period C. The common immediate complications after hepatectomy in the 207 patients operated on from 1985 to 1999 are shown in Table 4. Thirteen patients (6.3%) developed liver failure. Eight of the 14 patients (57.1%) with scores of 50 or more and 4 of the 28 patients (14.3%) with scores of 25–50 developed liver failure, with a significant difference (P = 0.0375) between the two groups. A significant difference ($P < 0.0001$) was also observed between scores of less than 25 (1 of 165 patients; 0.6%) and scores of 25–50. From these results, scores of 50 or more were determined as high-risk, scores of 25–50 as borderline, and scores of less than 25 as safe.

Since 2000, an MD-CT with an attached CT volumetric system (AZE system) has been installed at MWUH, allowing for the preoperative determination of the weight of the resected liver, excluding the tumor. Therefore, it has become possible to estimate the liver failure score before operation. Since then, no patients with a score of 50 or more have received a liver resection. Regarding the common immediate complications after hepatectomy, in the 145 patients in the period of 2000–2006 (Table 5), 1 of the 107 patients (0.9%) with scores less than 25 and 3 of the 38 patients (7.9%) with scores

Table 1. Patients' characteristics

	Period A; 1981–1984 (n = 28)	Period B; 1985–1999 (n = 207)	Period C; 2000–2006 (n = 145)
Age, years (mean ± SD)	55.7 ± 7.5	58.7 ± 9.1	60.7 ± 9.0
Sex (male/female)	27/1	129/78	89/56
Liver tumor	HCC	HCC	HCC
Child-Pugh classification			
A	13	154	129
B	14	49	16
C	1	4	0

A, Period of establishing the liver function risk evaluation formula; B, period of the validity check of the liver function score; C, period of use as liver function score before hepatectomy; HCC, hepatocellular carcinoma

Table 2. Operative methods for hepatectomy patients

	Period A; 1981–1984 (n = 28)	Period B; 1985–1999 (n = 207)	Period C; 2000–2006 (n = 145)
Right hepatectomy[a]	2	51	38
Left hepatectomy[b]	1	36	28
Middle bisegmentectomy	0	5	3
Lateral segmentectomy	5	22	16
Anterior segmentectomy	1	5	2
Posterior segmentectomy	0	17	10
Subsegmentectomy or partial resection	19	68	48

A, Period of establishing the liver function risk evaluation formula; B, period of the validity check of the liver function score; C, period of use as liver function score before hepatectomy

[a] Including a right trisegmentectomy

[b] Including a left trisegmentectomy

Table 3. Liver function in hepatectomy patients

Liver function test \ Term	Period A; 1981–1984 (n = 28)	Period B; 1985–1999 (n = 207)	Period C; 2000–2006 (n = 145)	P value A vs B; A vs C
Serum albumin level (g/dl)	3.30 ± 0.19 (2.5–3.6)	3.64 ± 0.52 (2.5–4.9)	3.62 ± 0.59 (2.4–4.5)	P = 0.0007; P = 0.0051
Hepaplastin test (%)	62.3 ± 12.1 (34–101)	76.3 ± 22.7 (39–150)	76.8 ± 20.4 (39–155)	P = 0.0016; P = 0.0004
GOT (U/l)	46.3 ± 28.4 (32–252)	45.9 ± 32.5 (7–219)	43.1 ± 27.6 (10–182)	ND; ND
ICG K value	0.101 ± 0.060 (0.03–0.11)	0.135 ± 0.052 (0.03–0.239)	0.138 ± 0.049 (0.05–0.228)	P = 0.0007; P = 0.0001
OGTT linearity index	1.22 ± 0.38 (0.4–3.1)	1.28 ± 0.52 (0.5–3.1)	1.24 ± 0.50 (0.5–3.0)	ND; ND
Resected liver weight (g)	279.8 ± 211.5 (12–556)	304.8 ± 321.5 (8.1–752)	432.4 ± 389.3 (17.1–821)	ND; ND

Data values are expressed as means ± SD; values in parentheses show the ranges (minimum–maximum)
A, Period of establishing the liver function risk evaluation formula; B, period of the validity check of the liver function score; C, period of use as liver function score before hepatectomy

Table 4. Surgical outcome after hepatectomy in the period for validation (1985–1999)

Mortality and morbidity \ Liver function score	Group A <25 (n = 165)	Group B 25–50 (n = 28)	Group C ≥50 (n = 14)	P value A vs B; B vs C
Hospital death (liver failure)	1 (0.6%)	4 (14.3%)	8 (57.1%)	P < 0.0001; P = 0.0375
Intractable ascites	0	4 (14.3%)	10 (71.4%)	P < 0.0001; P = 0.0265
Intractable pleural effusion	0	2 (7.1%)	6 (42.9%)	P = 0.0006; P = 0.0055
Intraabdominal abscess	4	2	2	
Intraabdominal bleeding	1	0	1	
Bile leakage	1	1	0	
Ileus	1	1	0	
Gastrointestinal bleeding	1	1	1	
Peptic ulcer	1	1	2	
Others	1[a]	0	1[b]	

[a] Myocardial infarction
[b] Pneumonia

Table 5. Surgical outcome after hepatectomy in the period of use of liver function score as risk score (2000–2006)

Mortality and morbidity \ Liver function score	Group A <25 (n = 107)	Group B 25–50 (n = 38)	P value
Hospital death (liver failure)	1 (0.9%)[a]	3 (7.9%)	P = 0.0224
Intractable ascites	0	3 (7.9%)	P = 0.0033
Intractable pleural effusion	0	3 (7.9%)	P = 0.0033
Intraabdominal abscess	1	0	
Intraabdominal bleeding	0	1	
Bile leakage	1	1	
Ileus	1	1	
Gastrointestinal bleeding	0	1	
Peptic ulcer	1	0	
Others	1[b]	1[c]	

[a] Patient with fulminant hepatitis after surgery
[b] Pneumonia
[c] Deep vein thrombosis

Table 6. Hospital stay after hepatectomy

Liver function score \ Term	Period B; 1985–1999	Period C; 2000–2006
<25	17.6 ± 12.7 (n = 165)	15.1 ± 3.2 (n = 107)
25–50	21.2 ± 14.5 (n = 28)	17.4 ± 5.7 (n = 38)
≥50	32.4 ± 20.6 (n = 14)	

Period B: <25 vs ≥50 *; 25–50 vs ≥50 **. Period C: <25 vs 25–50 ***

* P = 0.0005; ** P = 0.0475; *** P = 0.0226

B, Period of the validity check of the liver function score; C, period of use as liver function score before hepatectomy

of 25–50 developed liver failure, with a significant difference (P = 0.0224) between the two groups. There were three deaths among the patients with borderline scores of 25–50. One patient had a tumor infiltration into the IVC, resulting in unexpected intraoperative bleeding of 5640 ml; 1 patient died from an abscess formation at the hepatectomized stump; and 1 patient died from infection after re-operation for intestinal obstruction. Death occurred in one patient with a score below 25. This patient (score 11) was a hepatitis B carrier who developed fulminant hepatitis due to hepatitis B virus after hepatectomy, resulting in liver failure.

The mean postoperative hospital stay from 1985–1999 was 17.6 days in the group with a score of less than 25, and 32.4 days in the group with a score of 50 or more (P = 0.0005; Table 6). From 2000 to 2006, the mean postoperative hospital stay was 15.1 days the group with a score of less than 25 versus 17.4 days in the group with a score of 25–50 (P = 0.0226).

Discussion

The risk of postoperative hepatic failure is correlated closely with both the severity of active hepatitis and the degree of hepatic fibrosis. Although the indocyanine green (ICG) clearance test has been used to develop guidelines for hepatic resection,[10] in patients with jaundice and the presence of a shunt in the blood circulation, the recommended limit for a safe liver resection is difficult to determine.

Nowadays, in order to obtain a liver function score, we can use univariate Cox proportional hazard regression to assess the statistical significance of distinct candidate variables prior to inclusion in the formula. However, there was no concept of using the Cox proportional hazard regression test for this purpose in 1981. Therefore, when we formulated the liver function score in 1984, we selected five types of preoperative tests with different properties. First, we selected the serum albumin level (g/dl), which is regarded as a good indicator of chronic liver diseases, including cirrhosis.[12] Second, the hepaplastin test was used to indicate the protein synthesis capacity of the liver; it was originally a blood coagulation test to detect the activity of vitamin K-dependent coagulation factor.[13] Third, serum GOT activity was used to determine hepatitis activity. The histologic hepatitis activity correlates with the serum transaminase activity, and the amount of the enzyme that appears in the serum depends on the degree of liver damage and the extent of cell injury.[14] Fourth, ICG. K is related to the hepatic blood flow. The rate of elimination of ICG from the blood is delayed when the effective hepatic blood flow is lowered or the dye uptake of the hepatocytes is reduced as a result of cirrhosis or other diseases.[15–17] Fifth, the linear index of OGTT is related to the mitochondrial activity of the hepatocytes. Especially in cirrhosis, shunting occurs in portal vein blood and the blood supply to the liver parenchyma is reduced, leading to insulin resistance and a lowered glucose tolerance. Therefore, the linear index of 75-g OGTT is useful for the diagnosis of early-stage cirrhosis.[18,19] All of the above tests can be conducted routinely in hospital laboratories. Because one key to improve the safety of liver resection is to understand the relationship between liver volume and function, together with the weight of the resected liver (g), excluding the tumor weight, the above six parameters were used in order to construct the liver failure risk evaluation formula.

The advantage of the resection criteria based on this formula is the concept of "hepatic resection volume", but, because there is no established definition of this term, we could not compare our liver functional score with other liver functional scores. We adapted the weight of the resected liver, excluding the tumor weight, as one of the parameters for our formula; however, the resection ratio (the ratio of the weight of the resected liver [excluding the tumor weight] to the weight of the whole liver) could be more appropriate as a parameter, because the whole liver volume differs from person to person. Nowadays, we can easily estimate the remnant liver volume or weight preoperatively from MD-CT. However, in 1981, we could not get the information on remnant liver volume or weight from the preoperative images, and we had no choice other than to use the actual resected liver weight after surgery.

One problem in the formula construction was the small number of patients used in the analysis (28 in total, of whom 24 survived and 4 died). However, the liver failure evaluation formula was successfully constructed, because we had four typical post-hepatectomy liver failure patients with jaundice and ascites leading to death. When we validated the liver failure evaluation formula in the 207 patients from 1985 to 1999, it was evident that the postoperative liver failure rate was very high when the liver failure score was 50 or higher, and that it approached zero when the score was below 25.

In 2000, the MD-CT was installed at WMUH. Using this technique, we constructed three-dimensional images of the hepatic parenchyma, portal vein, hepatic vein, and tumor, and simulated the extent of the resection. Moreover, we used the software for calculating the weight of the resected liver excluding the tumor,[11] and the difference in the actual resected liver weight and the estimated weight was quite small, less than 10%, in the examination of 314 hepatectomy patients after 2000.[20] Currently, when the preoperative liver failure score exceeds 50, hepatectomy is not conducted. For such patients, those who satisfy the Milan criteria are indicated for liver transplantation; otherwise, the extent of resection is reduced or the surgical modality is changed to ablation in order to reduce the score to 50 or below. Patients with scores of 25–50 have a slightly reduced hepatic reserve capacity, and are predisposed to postoperative liver failure when there are complications, such as preoperative jaundice, massive bleeding, and increased duration of liver ischemia caused by repeated Pringle maneuvers. These patients are therefore classified as borderline.

Liver function is complex, and a successful tool to accurately assess quantitative functional hepatic reserve still needs to be established. However, it seems that the combination of distinct scores and preoperative MD-CT-based simulation may contribute to the achievement of safe resection in HCC patients with compromised hepatic function. The formula is sufficient for determination of the risk of post-hepatectomy liver failure and, thus, for making treatment decisions, as shown in Table 5. Therefore, hepatectomy can be conducted safely in patients classified as either borderline or safe, provided that no major complications occur either intra- or postoperatively. During 1985–1999, the "in-hospital death" in group B patients (score of 25–50) was 14.3%, whereas in 2000–2006 it was 7.9% in the same category of patients. The number of patients with Child-Pugh classification B and C was 26% (53/207) in 1985–1999 and 11% (16/145) in 2000–2006. The ratio was significantly higher in 1985–1999 than in 2000–2006. Therefore, as we can safely perform hepatectomy for patients with Child-Pugh classification A, our formula could be applied to patients with Child-Pugh classification B or C.

It seems that improvement of the outcome does not merely depend on the selection criteria used. Rather, it may be due to other factors, such as technical improvements in shortening operation time, reducing intra- and postoperative bleeding, and better patient nutrition care, as mirrored by the shorter hospital stay in our most recent group. Nowadays, the mortality after hepatectomy is below 2%, while no mortality is achieved at some high-volume centers.[21] At WMUH, the mortality rate of all hepatectomy patients from 1981 to 1984 was 6/64 (9.3%). However, during the time that we used used our formula for assessing liver function (1985–2006), the mortality rate for all hepatectomy patients decreased from 3.9% (15/386) in 1985 to 1999 to 1.3% (4/314) in 2000 to2006. The above findings allow us to conclude that the formula is valid for assessing the risk of post-hepatectomy liver failure.

References

1. Albers I, Hartmann H, Bircher J, Creutzfeldt W. Superiority of the Child-Pugh classification to quantitative liver function tests for assessing prognosis of liver cirrhosis. Scand J Gastroenterol 1989;24:269–76.
2. Lee SG, Hwang S. How I do it: assessment of hepatic functional reserve for indication of hepatic resection. J Hepatobiliary Pancreat Surg 2005;12:38–43.
3. Ohwada S, Kawate S, Hamada K, Yamada T, Sunose Y, Tsutsumi H, et al. Perioperative real-time monitoring of indocyanine green clearance by pulse spectrophotometry predicts remnant liver functional reserve in resection of hepatocellular carcinoma. Br J Surg 2006;93:339–46.
4. Hemming AW, Gallinger S, Greig PD, Cattral MS, Langer B, Taylor BR, et al. The hippurate ratio as an indicator of functional hepatic reserve for resection of hepatocellular carcinoma in cirrhotic patients. J Gastrointest Surg 2001;5:316–21.
5. Lee WC, Chen MF. Assessment of hepatic reserve for indication of hepatic resection: how I do it. J Hepatobiliary Pancreat Surg. 2005;12:23–6.
6. Merkel C, Gatta A, Zoli M, Bolognesi M, Angeli P, Iervese T, et al. Prognostic value of galactose elimination capacity, aminopyrine breath test, and ICG clearance in patients with cirrhosis. Comparison with the Pugh score. Dig Dis Sci 1991;36:1197–203.
7. Kwon AH, Ha-Kawa SK, Uetsuji S, Inoue T, Matsui Y, Kamiyama Y. Preoperative determination of the surgical procedure for hepatectomy using technetium-99m-galactosyl human serum albumin (99mTc-GSA.) liver scintigraphy. Hepatology 1997;25:426–9.
8. Kokudo N, Vera DR, Tada K, Koizumi M, Seki M, Matsubara T, et al. Predictors of successful hepatic resection: prognostic usefulness of hepatic asialoglycoprotein receptor analysis. World J Surg 2002;26:1342–7.
9. Kubo S, Tsukamoto T, Hirohashi K, Tanaka H, Shuto T, Takemura S, et al. Correlation between preoperative serum concentration of type IV collagen 7s domain and hepatic failure following resection of hepatocellular carcinoma. Ann Surg 2004;239: 186–93.

10. Lau H, Man K, Fan ST, Yu WC, Lo CM, Wong J. Evaluation of preoperative hepatic function in patients with hepatocellular carcinoma undergoing hepatectomy. Br J Surg 1997;84:1255–9.
11. Masumoto J, Sato Y, Hori M, Murakami T, Johkoh T, Nakamura H, Tamura S. A similarity measure for nonrigid volume registration using known joint distribution of targeted tissue: application to dynamic CT data of the liver. Med Image Anal 2003;7:553–64.
12. Fazakas J, Mandli T, Ther G, Arkossy M, Pap S, Fule B, et al. Evaluation of liver function for hepatic resection. Transplant Proc 2006;38:798–800.
13. Romanelli RG, La Villa G, Barletta G, Vizzutti F, Lanini F, Arena U, et al. Long-term albumin infusion improves survival in patients with cirrhosis and ascites: an unblinded randomized trial. World J Gastroenterol 2006;12:1403–7.
14. Dudrick SJ, Kavic SM. Hepatobiliary nutrition: history and future. J Hepatobiliary Pancreat Surg. 2002;9:459–68.
15. Schindl MJ, Redhead DN, Fearon KC, Garden OJ, Wigmore SJ. Edinburgh Liver Surgery and Transplantation Experimental Research Group (eLISTER). The value of residual liver volume as a predictor of hepatic dysfunction and infection after major liver resection. Gut 2005;54:289–96.
16. Lam CM, Fan ST, Lo CM, Wong J. Major hepatectomy for hepatocellular carcinoma in patients with an unsatisfactory indocyanine green clearance test. Br J Surg 1999;86:1012–7.
17. Wakabayashi H, Ishimura K, Izuishi K, Karasawa Y, Maeta H. Evaluation of liver function for hepatic resection for hepatocellular carcinoma in the liver with damaged parenchyma. J Surg Res. 2004;116:248–52.
18. Sasaya S, Yagi H, Yamaguchi M, Kigawa G, Nakano H, Midorikawa T, et al. Liver function assessed by increased rate of portal venous blood flow after oral intake of glucose. Eur J Surg 2000;166:112–8.
19. Huo TI, Lui WY, Huang YH, Chau GY, Wu JC, Lee PC, et al. Diabetes mellitus is a risk factor for hepatic decompensation in patients with hepatocellular carcinoma undergoing resection: a longitudinal study. Am J Gastroenterol 2003;98:2293–8.
20. Uchiyama K, Ueno M, Hama T, Kawai M, Tani M, Terasawa H, et al. Recurrence of primary hepatocellular carcinoma after hepatectomy–differences related to underlying hepatitis virus species. Hepatogastroenterology 2005;52:591–5.
21. Hasegawa K, Kokudo N, Imamura H, Matsuyama Y, Aoki T, Minagawa M, et al. Prognostic impact of anatomic resection for hepatocellular carcinoma. Ann Surg 2005;242:252–9.