Preoperative estimation of remnant hepatic function by fusion images of CT scans and single photon emission CT (SPECT) using $^{99m}$Tc-GSA.

(10/30/2009)

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Key words: hepatocellular carcinoma, hepatic resection, remnant hepatic function, fusion image of SPECT and X-ray CT
Abstract

Background: Assessment of hepatic functional reserve is important in hepatic resection. The aim of this study was to evaluate the value of hepatic asialoglycoprotein receptor (ASGP-R) analysis for the pre-operative estimation of remnant liver function in liver surgery.

Method: One hundred one patients undergoing hepatic resection for liver tumors were studied. Thirteen patients underwent preoperative percutaneous portal vein embolization (PTPE). Remnant hepatic function was estimated preoperatively using radioactivity on fusion images of both liver SPECT scans and CT scans using $^{99m}$Tc-diethylene-triamine pentacetic acid-galactosyl-human serum albumin.

Results: Mortality rate in patients with an ASGP-R concentration (receptor concentration) less than 400nM/L and preoperative total receptor amount of the remnant liver (R0-remnant) under 53nMoles (nM)/liver was 100% (3 out of 3 patients). Two patients with R0-remnant between 53 and 65 nM/liver and a receptor concentration less than 600nM/L developed liver dysfunction. The incidence of liver failure decreased inversely to the increase of R0-remnant. Conclusion: Combining receptor concentration and R0-remnant detected on fusion images is very useful to evaluate the risk of postoperative liver failure.

Introduction

It is frequently necessary before hepatectomy to evaluate liver function and to estimate the remaining liver function. Assessment of hepatic
functional reserve is one of the most important issues in hepatic resection\textsuperscript{1-10}. This is especially true for hepatocellular carcinoma, in which the majority of patients have concomitant liver damage, such as liver cirrhosis, which limits hepatic resectability. Extended hepatectomy, defined as the resection of five segments, as described by Couinaud, is still associated with higher operative morbidity and mortality\textsuperscript{11}. Recently, there has been emphasis on linking complications after extended hepatic resection to the small functional amount or small volume of remnant liver left after resection rather than to the amount of liver resected\textsuperscript{12}. To estimate hepatic functional reserve, $^{99m}$Tc-diethylene tri-amine pent acetic acid-galactosyl-human serum albumin ($^{99m}$Tc-GSA), a radiopharmaceutical that binds specifically to hepatic asialo-glycoprotein receptor, has been developed and used clinically for hepatic functional estimation\textsuperscript{13-15}. Because asialo-glycoprotein receptor is a natural superficial antigen of viable hepatocytes, the uptake of $^{99m}$TcGSA is independent of biochemical processes and allows direct estimation of the functioning hepatocyte mass\textsuperscript{16}. In addition, the distribution of $^{99m}$Tc GSA in the liver is not dependent on liver blood flow\textsuperscript{8}. Vera et al.\textsuperscript{13} developed an automated kinetic analysis method to measure a subject’s hepatic asialoglycoprotein receptor concentration from $^{99m}$TcGSA heart and liver time-activity data. Previous studies have demonstrated that the determination of receptor concentration is a reproducible, relatively simple to perform, sensitive, and bilirubin-independent method of evaluating the progression of liver disease\textsuperscript{18,19}. $^{99m}$Tc-GSA is presently more accurate in documentary compensatory
hyperplasia and a shift of functional reserve to the planned remnant of a more than four-segment hepatic resection than indocyanine green (ICG) retention test combined with CT\textsuperscript{5}. A few reports\textsuperscript{3, 7, 8, 9} have dealt with regional hepatic functional estimation. In the present study, hepatic asialoglycoprotein receptor concentration was calculated by Vera’s method\textsuperscript{13, 20} and hepatic functional reserve was estimated with \textsuperscript{99m}Tc-GSA SPECT scintigraphy fused with CT scans. Equally, a functional estimate of the remaining liver volume was calculated using fusion images of contrast-enhanced CT scans and \textsuperscript{99m}TcGSA-SPECT preoperatively.

In this way, hepatic asialoglycoprotein receptor (ASGP-R) analysis was preoperatively performed using fusion images of CT scans and \textsuperscript{99m}Tc-GSA SPECT to predict postoperative liver failure after hepatic resection.

Methods

Subjects. From October 1995 to March 2004, \textsuperscript{99m}Tc-GSA studies were performed in patients who underwent hepatectomy for liver tumors at Okayama University Hospital (Table 1). Patients were either operated for hepatocellular carcinoma in cirrhotic livers (Child Pugh A or B cirrhosis), or for primary or secondary cancers in a background normal liver. All patients with hepatocellular carcinoma with liver cirrhosis who underwent extended hepatic resection matched the criteria for operability proposed by Miyagawa et al.\textsuperscript{21} using both serum total bilirubin and ICG retention at 15 minutes.

Computed Topographic Hepatic Volumetric CT scanning
Prior to operation, unenhanced helical CT scanning was performed of the entire liver with 7-mm collimation at 7-mm intervals using a High Speed Advantage CT scanner (GE Medical Systems, Milwaukee, Wis.) during a single breath-hold. When it was difficult to detect the edges of a segment or tumor, contrast-enhanced helical CT scanning was performed three times after the start of injecting 100 ml iohexol (Omnipaque 300-; Daiichi Pharmaceutical Co., Tokyo, Japan) via an antecubital vein at 3 ml/s. Total liver volume (TLV) was calculated by multiplying the area of each cross-sectional liver image by the slice thickness (1 cm in most cases)\(^{22}\). Tumor volume (TV) was similarly estimated by manually tracing each tumor border. In cases of multiple tumors, TV was the sum of all tumor volumes. Hepatic parenchymal volume (functional liver volume, FLV) was calculated by subtracting TV from TLV. The volume of the resected specimen (WR) was calculated as weight of resected liver divided by 1.05\(^{23}\). The resected parenchymal fraction and future remnant liver (FRL) were calculated as follows:

\[
\text{Resected parenchymal fraction} = \frac{(WR - TV)}{FLV}, \quad FRL = TLV - WR
\]

99mTc GSA liver scintigraphy.

All patients received a single dose of 185 MBq (5 mCi) of \(^{99m}\)Tc coupled with 3mg GSA (Nihon Medi-Physics, Nishinomiya, Japan) intravenously. After the injection of \(^{99m}\)Tc-GSA, dynamic imaging was performed with the patient in the supine position using a GCA-7200 A/DI (Toshiba Medical Systems, Tokyo, Japan) with a large-field-of-view gamma camera.
with two head detectors, a low-energy and high-resolution parallel-hole colli-
mator, and data were processed by GMS-5500 A/DI (Toshiba Medical Systems, Tokyo, Japan) as previously described\textsuperscript{7}.

Time-activity curves for the heart and liver were generated from ROIs for the whole liver and the precardiac region\textsuperscript{7}. The hepatic uptake ratio (LHL\textsuperscript{15\textsuperscript{17}}) of $^{99m}$Tc GSA was calculated by dividing liver activity at 15 min by heart plus liver activities at 15 min\textsuperscript{17}. The following modification to the protocol was made to replace the counting standard: immediately after the withdrawal of 1.0 mL. $^{99m}$TcGSA into a 3-mL syringe from the labeling vial, activities in the syringe and vial were measured in a dose calibrator. After injection, residual activity within the syringe was measured using the same dose of calibrator as for previous measurements. The conversion factor was also determined by measuring the activity of the $^{99m}$Tc-pertechnate sample (5 mCi, 1 mL in a 3-mL syringe) in the dose calibrator and measuring the cpm of a 0.5 mL sample from 5000-fold dilution of the same $^{99m}$Tc-pertechnate solution together with 0.5ml of serum taken out at 3 min after injection of $^{99m}$Tc-GSA from a cubital vein of the patient who was injected $^{99m}$Tc-GSA simultaneously. In addition, patient body weight and hematocrit data were measured. These values and the time at which they were measured were entered into the Tsuboi’s computer program\textsuperscript{3}. To evaluate the receptor concentration (nmol/L), the time-activity curve of liver and heart data with $^{99m}$Tc-GSA was analyzed using a three-compartment, bimolecular kinetic model\textsuperscript{13}. An automated simulation computer program\textsuperscript{3}, running on a personal computer.
(PC-9501RX; NEC Computer Inc., Tokyo, Japan), repeatedly adjusted hepatic receptor concentration and other kinetic parameters representing hepatic plasma flow F (L/min), hepatic plasma volume (L), extra hepatic plasma volume (L) and the receptor-99mTcGSA forward-binding rate constant kb (µmol/L/min). The simulation program automatically stopped the adjustments when the computer simulations matched the shape of the liver and heart time-activity curves. If the curve-fit results met a set of criteria in which the difference in the minimum least squares value between the curve and the origin data curve after compartment analysis was set to converge equal to or less than 0.1, the program provided output on the estimate and standard error of each kinetic parameter. Total hepatic ASGP-R amount (nM/liver) was calculated by

Total hepatic ASGP-R amount = (receptor concentration) x (hepatic plasma volumes) x 1000

Cross-slices of 1 cm liver from CT scans and SPECT were aligned and a transection line, placed on hepatic cross-slices of CT scans by marking the hepatic vein on contrast-enhanced helical CT as shown (Fig.1), was simultaneously placed on every one cm liver cross-slice of SPECT before hepatic resection. After the transection line was drawn systematically using anatomy on SPECT based on CT scans, the future liver remnant with the intended resection line was manually determined, and then total receptor amount of the remnant liver (R0-remnant) was calculated using the remaining liver radioactivity obtained (Fig.1).

R0-remnant (nM/liver) = Total hepatic ASGP-R amount (nM/liver) x
(remnant liver radioactivity/total liver radioactivity)

*Portal vein occlusion.*

Percutaneous right transhepatic portal vein embolization was performed in some cases of hepatic tumor in which the estimated preoperative R0-remnant was less than 53—80nM/liver to increase the size of the future remnant liver (FRL). PTPE was performed using an ipsilateral approach, described in detail elsewhere \(^7, 24, 25, 26\). The effect of PTPE was also evaluated from fusion images. Portal vein embolization should be considered when the prospective postoperative liver volume is less than 20\% or less than 40\% in patients with known liver cirrhosis\(^26\). In principle, PTPE is indicated for patients with resected parenchymal fraction exceeding 60\%\(^2\).

Serial contrast enhanced CT scans and \(^{99m}\text{Tc-GSA}\) of the whole body were taken pre-and postoperatively (3 weeks and 3 months and/or 6 months after operation).

*Signs of Postoperative Liver Failure*

Signs of postoperative liver failure were evaluated from 7 to 21 days after hepatic resection: transient elevation of total serum bilirubin (more than 3.0 mg/dL), ascites, pleural effusion and hepatic encephalopathy. The presence of ascites and pleural effusion was judged 7 days after liver resection. Patients were defined as having hepatic encephalopathy when they developed Sherlock’s grade \(^27\) or more encephalopathy (drowsy,
inappropriate behavior) with elevated serum ammonia levels (more than 100µg/dl).

**Statistical Analysis**

All data are expressed as means ±SD. The Wilcoxon signed-ranks test, Student’s t-test and Mann-Whitney test compared data for two groups. To compare the performance of factors significant in univariate analysis, the areas under the receiver operating characteristics (ROC) curves were calculated. Differences in ROC curve areas were analyzed using the method of Delong et al. All statistical analyses were performed to identify factors that were independently associated with the detection of postoperative liver failure using the SAS package (version 8) and JAP software (version 5.1; SAS Institute, Inc., Cary, NC). P-values smaller than 0.05 were considered significant. Bonferroni correction was used for multiple comparisons of areas under ROC curves and P<0.05 was considered significant.

**Results**

A total of 101 patients were studied (Table1). Hepatic sub-segmentectomy was performed in 11 patients, monosegmentectomy in 18, dissegmentectomy in one, right or extended right heptatectomy in 57, and left or extended left heptatectomy in 14 patients. All patients were followed up for 3—28 months after operation, and 3 patients died of liver failure. One of 3 patients with severe hepatic dysfunction after liver resection suffered biliary infection, developed severe hepatic dysfunction and died. The most common postoperative complications were ascites, pulmonary...
failure, bleeding or repeated bleeding, and liver failure\textsuperscript{19}.

1. ROC analysis for predicting liver failure.

Seventeen of the 101 patients developed liver failure (Table 2). The data of preoperative four parameters (hepatic receptor concentration, amount of remnant hepatic receptor, the indocyanine clearance index (KICG) and LHL15 which differed significantly between patients with or without liver failure were used for ROC regression analysis. Intra-operative blood loss was (350~2850 ml (mean, 1560±680 ml)). Blood loss was excluded from the ROC analysis, because this value was not known before hepatectomy.

Areas under the ROC curves of hepatic receptor concentration, R0-remnant, KICG, and LHL15 were 0.803, 0.969, 0.748, and 0.738, respectively. The area under the ROC curve of R0-remnant was significantly larger than that of hepatic receptor concentration (p=0.024), KICG (P=0.007) and of LHL15 (P=0.002); however, the superiority of R0-remnant was observed only against KICG and LHL15 after correction for multiplicity (Fig. 2).

2. Factors of SPECT predicting liver failure after hepatectomy.

Hepatic receptor concentration significantly decreased from 683±0.24 nM/L to 565±32 nM/L 3 weeks after the operation (P< 0.001). Three of the four cirrhotic patients showed marked decreases in hepatic receptor concentration after hepatic resection. The amount of hepatic receptor decreased from 228±12 nM/liver to 130.9±62.7 nM/liver in 61 examined cases after 71 major hepatic resections. In these cases, R0-remnant significantly increased to 179 ± 87 nM/liver (P = 0.035) 3 weeks after the
operation. This increase was more prominent in the 23 non-cirrhotic patients (from 126±11 nM/liver to 247±10 nM/liver (P = 0.008)). On the other hand, a decrease of amounts of total hepatic receptor was observed 3 weeks after hepatic resection in 37 cirrhotic patients (Fig. 3).

For the 101 patients undergoing hepatic resection the receptor concentration was plotted against the R0-remnant (Fig. 4). Thirteen patients with HCC and liver cirrhosis and one of HCC with chronic hepatitis and R0-remnant and hepatic receptor concentration values below 65 nM/liver and 600 nM/L respectively, are distributed in the lower left area of Figure 4. These patients developed liver failure after hepatic resection. Three patients with HCC and liver cirrhosis died within 5 months and the other 11 of 14 patients showed transient liver failure (Figure 4). The mortality rate in patients with cirrhosis with R0-remnant under 53 nM/liver and hepatic receptor concentration under 400 nM/L was 100% (3 out of 3 cases). On the other hand, 3 patients with normal background liver and R0-remnant below 53 nM/L and more than 600 nM/L of hepatic receptor concentration, are distributed in the lower right area of Figure 4. Only one of three patients developed transient liver failure. Liver failure is apparently unlikely to occur if R0-remnant is equal to or more than 100 nM/liver.

3. Effect of preoperative PTPE

A total of 17 patients underwent PTPE. In 7 patients undergoing hepatectomy with almost normal liver function, R0-remnant of the future remnant (nonembolized) lobe improved from 77.06 ±12.91 nM/liver (range,
56.3—85.0nM) before PTPE to 124.8 ±22.28 nM/liver (range, 95.6—158.3nM) 3—4 weeks after PTPE and 176.39± 41.65 nM/liver 3 months after operation (p = 0.075). Also, in 4 of 5 patients with HCC with liver cirrhosis, the value of hepatic receptor concentration 3 weeks post-hepatectomy showed a temporary decline, but these patients did not develop liver failure. Patients with a HCC and cirrhosis and a R0-remnant value of 53—85nM/Liver after PTPE, showed less post-operative regeneration (Fig. 5). In a HCC patient with liver cirrhosis treated with PTPE, evaluation of the effects of occlusion of the right portal venous branch revealed discrepancy between CT scans and $^{99m}$Tc GSA liver SPECT (Table 3). R0-remnant estimated by CT scans was less than that obtained by hepatic $^{99m}$TcGSA-SPECT. Also, the preoperative R0-remnant values after PTPE identified from the radioactivity of the remaining liver with SPECT were 1.3 ± 0.11 times (p = 0.048) larger than the R0-remnant values identified from the volume ratio using CT scan post-PTPE in 17 hepatic tumor cases (Fig. 5, Table 3). The increase in the R0-remnant value of the unembolized lobe by PTPE was more than volumetric increment, but the increase in the number of receptors in the regeneration period after hepatic resection tended to be less than the volumetric increment (Table 3).

Discussion

In the present study, the value of pre-operative estimation of remnant hepatic function following hepatectomy by using fusion images of CT
scans and SPECT using $^{99m}$Tc GSA with evaluated. The risk of post resectional liver failure could be predicted with reasonable accuracy using R0 remnant and amount of R0 concentration. Equally this technique was able to quantify the refractive response both after portal branch embolization and following hepatectomy.

Measuring the remnant liver volume using planar images obtained by $^{99m}$TcGSA scintigraphy is not accurate, but by making a cut line in each section of the trans-axial or frontal SPECT image, the measurement of the remnant liver hepatic binding concentration is precise. The future remnant liver R0-remnant (nM/liver) could be calculated correctly preoperatively using a fusion image of $^{99m}$Tc-GSA-SPECT and contrast enhanced CT scans. Using fusion images of CT and SPECT, a resection line was drawn manually on SPECT using anatomy based on CT, to allow for calculation of the volume of the future liver remnant. Therefore, the radioactivity within the volume of the future liver remnant could be estimated and the R0-remnant values could be calculated.

Many authors have reported methods for assessing liver volume and function with standard CT and/or $^{99m}$Tc-GSA SPECT or $^{99m}$Tc-mebrofenin scintigraphy. There may be a functional difference between the two main liver lobes in the uptake of 123-metaiodobenzylguanidin and $^{99m}$Tc-dimethyliminodiacetic acid (HIDA). The accumulation of $^{99m}$Tc-GSA in the liver parenchyma is more stable than HIDA, whereas HIDA gives more information on biliary excretion at 5 min after intravenous injection.
The degree of regeneration is highly dependent on the remnant liver volume ratio\textsuperscript{25} and the degree of impairment of remnant liver function, so the degree of functional regeneration differs among patients. $^{99m}$Tc-GSA SPECT proved to be more accurate than CT in the evaluation of remnant liver function\textsuperscript{7}. In case of HCC with liver cirrhosis, chronic hepatitis or fibrosis\textsuperscript{37}, hepatic dysfunction in the hepatic segment or lobe containing HCC was greater than that in the segment or lobe without HCC because liver parenchyma around the tumor was damaged by mechanical compression that may have occurred due to compression of the vessels\textsuperscript{38} and bile ducts by the tumor\textsuperscript{39}. Comparing hepatic CT and hepatic SPECT images obtained using $^{99m}$TcGSA, the defect seen on SPECT images was larger than the tumor seen on CT. The preoperative R0-remnant values estimated from the radioactivity of the remaining liver with SPECT were larger than the R0-remnant values identified from the volume ratio using CT in patients after PTPE (Fig. 5). This discrepancy was probably due to the above factors\textsuperscript{7}. Mitsumori\textsuperscript{7} reported that in all 4 patients, including 3 with HCC with liver cirrhosis and one with cholangio-cellular carcinoma with normal liver, the remnant liver volume ratio was higher in the evaluation by GSA than by CT before portal vein occlusion and, 2–3 weeks after portal vein occlusion, it was markedly increased with GSA as compared with CT. Therefore, remnant liver function should probably be predicted using $^{99m}$Tc GSA-SPECT rather than CT\textsuperscript{7}, although Kokudo\textsuperscript{8, 30} estimated the total hepatic receptor amount of the remnant liver (R0-remnant) using hepatic receptor concentration and the rejected
parenchyma fraction by CT scans.

Liver SPECT using $^{99m}$Tc GSA is more useful than CT to predict remnant liver function accurately before hepatic resection and to evaluate changes in regional liver function after unilateral occlusion of the portal vein. The increased in total amounts of hepatic receptor after hepatic resection was higher in the non-liver cirrhosis group than in the liver cirrhosis group (Fig. 5). Combining hepatic receptor concentration and R0-remnant detected on the fusion images with CT and SPECT is very useful to evaluate a higher risk for postoperative liver failure. The ICG test has presently been shown not to correlate very well with postoperative liver failure$^5$. The striking drop in hepatic receptor concentration observed at 3 weeks post-rejection in cirrhotic patients may indicate an exaggerated postoperative change.

Cirrhotic patients and patients with a low R0-remnant are at higher risk for postoperative liver failure$^{8,17}$. Hwang$^9$ reported that of 5 patients who had postoperative complications due to hepatic insufficiency, 2 died of postoperative hepatic failure within 2 months after operation. Based on the current data, it is recommended that patients with estimated R0-remnant below 53 nM/liver and hepatic receptor concentration less than 400 nM/L are contraindicated for surgery. In such instances, surgeons should reduce the extent of resection to increase the R0-remnant if possible. The combination of hepatic receptor concentration and R0-remnant best detected liver failure.

On the other hand, Dinant$^{32}$ reported that preoperative measuring of $^{99m}$Tc-mebrofenin uptake in the future remnant liver on hepatobiliary
scintigraphy proved more valuable than measuring the volume of the future remnant on CT in assessing the risk of liver failure and liver failure related mortality after partial liver resection.

PTPE can be used to reduce the size of the resected tissue and to increase the volume of the residual liver. In principle, PTPE is indicated for patients with resected parenchymal fraction exceeding 60%\textsuperscript{21}. In order to induce hypertrophy on the contralateral side and increase the size of FLR, PTPE was performed in 17 patients with hepatic tumors in which the R0-remnant value was 53—85 nM/liver. Many studies have shown that PTPE is effective, particularly for hypertrophy of non-embolized hepatic segments\textsuperscript{35, 40}. Based on these previous studies \textsuperscript{14, 25, 40, 41}, if PTPE is performed before hepatectomy in patients with a damaged liver, extended hepatectomy may be considered. After occlusion of the right portal vein, liver uptake markedly decreased below the cut-off level in the right lobe, and an area of increased tracer accumulation was noted in the left lobe on 99m\textsuperscript{Tc} GSA liver scintigraphy. Atrophic changes in the right lobe and compensatory morphological hypertrophy of the left lobe were not as evident when evaluated by CT\textsuperscript{42} or ultrasonography\textsuperscript{43} as by 99m\textsuperscript{Tc} GSA liver scintigraphy. The relative increase of radioactivity in the future remnant lobe compared to the volumetric increment was reported\textsuperscript{7} in patients with a good clinical course after PTPE pre-hepatectomy. Cells in the nonembolized lobe entered a highly active phase of proliferation within 2 weeks after portal vein embolization leading to a net gain of functional hepatocyte mass \textsuperscript{44}.

Hepatic resection could be safety performed by using PTPE for patients
with 53—80nM/liver of R0-remnant. PTPE can increase R0-remnant values and $^{99m}$Tc GSA liver scintigraphy can then correctly assess the volume of future remnant liver and therefore expand the range of hepatic resection.

Acknowledgements: This work was supported in a part by a Japanese Ministry of Health grant (no. 10670474). The authors would like to thank Dr Toshihiro Higashi (Department of Internal Medicine, Okayama Citizen’s Hospital) for useful discussion. We thank Prof. Hajime Tsuboi (The Engineering Department Information Processing, Fukuyama University) and Dr Yoko Fujisawa (Toshiba Medical Systems Co. Ltd, Tokyo, Japan) for their programming of the Vera’s radio pharmacokinetic modeling of technetium-99m galactosyl-neoglyco-albumin and technical support of this study. We also thank Dr. Yoichi M. Ito (Department of Biostatistics, School of Public Health, and The University of Tokyo) for the analysis of ROC curves. The authors would like to thank Professor Kazuhide Yamamoto and Dr Shinichiro Nakayama (Department of Gastroenterology and Hepatology, Okayama University Graduate School of Medicine, Dentistry and Pharmaceutical Sciences) and Professor Noriaki Tanaka (Department of Gastroenterological Surgery, Transplant, and Surgical Oncology Okayama University Graduate School of Medicine, Dentistry and Pharmaceutical Sciences) for critically revising the paper.

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Figure 1. Three-dimensional hepatic resection images on hepatic CT (a, b) and change of future remnant liver (b) in the clinical course of a patient with HCC and liver cirrhosis treated with PTPE prior to resection of the right hepatic lobe.

A fused image of hepatic SPECT and CT was created after adjusting the positions of hepatic SPECT and CT images. After a cutting line was placed systematically on hepatic CT images along the hepatic vein (d), the line was placed on all hepatic $^{99m}$Tc-GSA-SPECT slices (c). In this way three-dimensional resection images on hepatic CT before (a) after PTPE (b) and $^{99m}$Tc-GSA-SPECT image at day 230 after hepatic resection (e) were obtained. R0-remnant before PTPE (a), 18 days after PTPE (b), and post-hepatic resection (e) was 78.9, 84.2 and 353.3 nM/liver respectively.

Figure 2. ROC analysis factors predicting liver failure using $^{99m}$Tc-GSA-SPECT and CT before hepatic resection.

ROC curves were constructed based on data from 17 of 101 patients who developed liver dysfunction after hepatic resection, the receiver operating characteristic curves (ROC) showed that R0-remnant was
superior to receptor concentration, KICG or LHL15. Area under ROC curve of R0-remnant was significantly larger than that of receptor concentration (p=0.024), KICG (p=0.007) and of LHL15 (p=0.002).

Figure 3. Total Receptor amount of remnant liver pre-hepatectomy, at 3 weeks post-hepatectomy, and values 2—3 months after hepatic resection in the future remnant liver between liver cirrhosis and chronic hepatitis.

Solid lines, chronic hepatitis patients; dashed lines, cirrhotic patients; dot line. Abbreviations: CH, chronic hepatitis; LC, liver cirrhosis; LCd 1, 2, 3: the patient with HCC and liver cirrhosis (LC) died of liver dysfunction after hepatic resection respectively.

Values of R0 remnant showed significant difference between CH and LC post OP 3 weeks (\( ∗\) p=0.0004) and post OP 2-3 months (\( \dagger\) p=0.000005).

Figure 4. Relationship between preoperative receptor values of remnant liver and receptor concentration in non-cirrhotic and cirrhotic patients.

Abbreviations: LC dead: tumor-bearing liver was cirrhotic and patient died of liver dysfunction after hepatic resection; LC dysf: cirrhotic liver and post resectional liver failure; Ch dysf: chronic hepatitis with dysfunction; N dysf: normal liver with dysfunction; CH, LC and N: chronic hepatitis, liver cirrhosis and normal.

Figure 5. Changes of receptor amount of the remnant liver in patients
undergoing PTPE before hepatectomy (n=17). In 5 patients with HCC with liver cirrhosis, 5 of HCC with chronic hepatitis and 7 of liver cancer with almost normal liver, PTPE was performed for the right portal vein before right hepatic rejection.

Table 1. Patient characteristics.

Table 2. Comparison of preoperative various liver functions using $^{99m}$Tc-GSA SPECT between patients with liver dysfunction and no liver dysfunction after hepatic resection.

Table 3. Comparison between regeneration rate of remnant hepatic volume and receptor amounts of the remnant liver estimated before and after PTPE as well as before and after hepatectomy.