

Functional assessment versus conventional volumetric assessment in the prediction of operative outcomes after major hepatectomy

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Purpose. In this study we examined whether conventional future remnant liver volume (FR volume) or function (FR function) better predicted the operative outcome after major hepatectomy.

Methods. Of 510 patients who underwent hepatectomy for various indications, 133 patients with major hepatectomy were enrolled in this study. FR volume and the corresponding FR function routinely were measured with a ^{99m}Tc-GSA scintigraphy single-proton emission computed tomography fusion system. FR function was defined as the future remnant liver uptake ratio of ^{99m}Tc-GSA per whole liver by single-proton emission computed tomography. FR volume or function in cases with insufficient FR volume or function required for major hepatectomy were defined as marginal.

Results. Morbidity, liver dysfunction-related morbidity, and mortality after major hepatectomy occurred in 40 (30%), 10 (7.5%), and 8 (5.7%) patients, respectively. Thirty-two of the 133 patients were diagnosed as marginal using FR volume, but only 11 patients were diagnosed as marginal using FR function. These results indicated that 21 patients (16%) were switched to the safe group using functional assessment.

Operative outcomes in patients with safe FR function (n = 122) were equivalent to those of patients with safe FR volume (n = 101), but patients with marginal FR function (n = 11) had substantially worse outcomes than patients with marginal FR volumes (n = 32). Logistic regression analysis identified marginal FR function, but not volume, as a risk factor for worse operative outcome after major hepatectomy. Portal vein embolization induced the substantially greater FR function compared with FR volume. Although liver volume equally corresponds to liver function under normal conditions, liver cirrhosis was greatly associated with the major discrepancy (more than 10%) in patients without portal vein embolization.

Conclusion. Functional assessment for future remnant liver identified patients who were eligible for curative hepatectomy despite a marginal status based on conventional volumetric assessment. Thus, marginal FR function is a better predictor of operative outcome after major hepatectomy than FR volume, especially in patients with nonhealthy liver. (*Surgery* 2015;157:20-6.)

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HEPATIC RESECTION provides the best hope of cure in patients with various liver cancers, but major hepatectomy is associated with substantial morbidity

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and mortality rates. Liver dysfunction is the major cause of mortality and morbidity after hepatectomy, and it develops as the result of insufficient remnant liver function. Therefore, an accurate assessment of the future remnant liver function (FR function) is crucial in the preoperative workup of patients requiring major hepatectomy, especially patients with underlying parenchymal liver disease. Various methods to preoperatively evaluate hepatic functional reserve have been advocated. Passive liver function tests, including tests of biochemical

parameters (eg, serum levels of bilirubin, albumin, and prothrombin time), and clinical grading systems (eg, Child-Pugh Classification) do not accurately predict operative outcomes after hepatectomy.¹

Dynamic quantitative liver function tests, such as the indocyanine green (ICG) clearance test² and 99mTc-galactosyl human serum albumin (99mTc-GSA) scintigraphy,³ have been reported to be more useful for predicting postoperative liver dysfunction after hepatectomy. These tests assess the elimination process of a substance that is cleared and/or metabolized almost exclusively by the liver.¹ Preoperative liver function tests confirm which patients can safely undergo major hepatectomy, but severe complications, including postoperative liver failure, are not eliminated entirely. Indeed, the reported morbidity and mortality rates after major hepatectomy remain high (range 12.9–47.1%^{4,8} and 2.6–7.4%,^{4,9} respectively) despite advancements in operative techniques and perioperative care. These results support the need for FR-specific function tests rather than global liver function tests as measured by ICG or other methods during the preoperative assessment. One of the underlying problems with preoperative assessments for reserved liver function is that conventional tests that use dynamic quantitative liver function only measure global liver function before hepatectomy and not FR function after hepatectomy specifically.¹

Liver surgeons without tools to assess FR functions determine liver tumor resectability by using future remnant liver volume (FR volume). FR volume calculations are based on the concept that liver function is related to liver volume. However, recent developments in medical radiology have revealed that liver volume does not necessarily reflect liver function, especially in patients with compromised livers.^{10,11} These results have raised questions regarding whether FR function or FR volume is a predictive factor for operative outcome after major hepatectomy. The newly developed 99mTc-GSA scintigraphy single-photon emission computed tomography (SPECT)/computed tomography (CT) fusion system allows for the simultaneous evaluation of any part of the liver volume and the corresponding liver function.¹² This study determined whether functional assessment (FR function) or volumetric assessment (FR volume) of the future remnant liver is superior for the prediction of morbidity, liver dysfunction-related morbidity, or mortality after major hepatectomy.

PATIENTS AND METHODS

Patients. A total of 510 patients underwent hepatectomy for various indications in the Department of Gastroenterological Surgery, Kumamoto University, from May 2005 to December 2012. Within this population, 133 patients with liver tumors (hepatocellular carcinoma in 85, colorectal liver metastasis in 22, intrahepatic cholangiocarcinoma in 14, combined hepatocellular carcinoma and cholangiocarcinoma in 2, benign and others in 10) underwent major hepatectomy (ie, a resection of three or more Couinaud's segments) and were enrolled in this study (patient characteristics are shown in [Table I](#)).

The hepatitis B surface antigen was detected in 24 patients, hepatitis C antibody in 41, and neither of them (non-B, non-C) in 68 patients. Liver cirrhosis was histologically proven in 25 patients (19%). The following types of major hepatectomy were performed in these patients: right hepatectomy in 58 patients (44%), right hepatectomy extended to include the middle hepatic vein in 15 patients (11%), left hepatectomy in 21 patients (16%), left hepatectomy extended to include the middle hepatic vein in 22 patients (17%), extended right hepatectomy in 6 patients (4%), extended left hepatectomy in 5 patients (4%), and mesohepatectomy in 6 patients (4%). One patient underwent bile duct resection.

Additional procedural details are given in [Supplementary Table I](#). Patients were considered operable if all diagnosed tumors could be treated by radical resection; with (1) macroscopically negative operative margins and (2) sufficient (safe) FR volume or function based on $ICGR_{15}$ and Makuuchi's criteria¹³ ([Supplementary Table II](#)). For example, in patient with value of $ICGR_{15}$ less than 10%, 20%, 30%, or 40%, a lowest limit of safe future remnant liver volume or function was 40% (35% in normal liver), 60%, 80%, 90%, respectively. FR volume or function in cases with insufficient FR volume or function required for major hepatectomy were defined as marginal. Preoperative portal vein embolization (PVE) was performed before major hepatectomy in 40 (30%) patients. In the cases with both of marginal FR volume and function, a hepatectomy was undertaken in considering of the other data such as LHL15 and general condition only if the patient had a desire to undergo operation and informed consent had been obtained. Perioperative data were prospectively collected, and the association between FR function and operative outcomes after major hepatectomy were retrospectively analyzed. The ethical committee of our institute approved this trial.

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