Acta Med. Nagasaki 53: 15−21

Operative Outcome of Cardiac Surgery in Patients with Liver Cirrhosis

Kentaro YAMANE, Kenta IZUMI, Shiro YAMACHIKA, Koji HASHIZUME, Kazuyoshi TANIGAWA, Takashi MIURA, Wataru HASHIMOTO, Tomohiro ODATE, Shun NAKAJI, Kiyoyuki EISHI

Department of Cardiovascular Surgery, Nagasaki University Hospital, Nagasaki, Japan

Introduction: A retrospective study was performed to investigate the relationship between the severity of liver cirrhosis and the outcome of cardiac surgery. **Methods and Results:** Twenty-one patients with liver cirrhosis underwent cardiac surgery in our institution. According to the Child-Pugh classification, 13 patients were in class A, 7 in class B, and 1 in class C. Coronary artery bypass grafting was performed in 7 patients, surgery for valvular disease in 10 and other procedures in 4. Major postoperative complications occurred in 8%, 29%, and 100% for Child-Pugh class A, B, and C, respectively. Preoperative hemoglobin level was significantly lower in the patients with postoperative complications. None of 4 patients underwent coronary revascularization using off-pump procedure or mini-pump system experienced major complication. The operative mortality was 0%, 14%, and 0% for Child-Pugh class A, B, and C, respectively. **Conclusions:** Although the overall mortality rate in patients with liver cirrhosis was acceptable in our study, the incidence of severe complications, such as prolonged ventilation, mediastinitis and irreversible hepatic insufficiency was problematic in Child-Pugh class B and class C patients. Application of less invasive cardiac surgery, such as mini-pump system or off-pump procedure will improve the operative outcome in such patient group.

ACTA MEDICA NAGASAKIENSIA 53: 15−21, 2008

Keywords: Cardiac surgery; Liver cirrhosis; Mortality and morbidity; Child-Pugh classification

Introduction

Perioperative management for cardiac surgery in patients with liver cirrhosis is often complicated due to various factors associated with altered liver function, such as bleeding tendency, undernutrition, susceptibility to infection, and difficulty in controlling body fluid balance.[1,2] The surgical mortality rate in such patient group has been reported to be 18-80% in class B and 67-100% in class C according to the Child-Pugh classification.[1-5] It is important to investigate the relationship between the severity of liver disease and surgical outcomes, and clarify the indication for cardiac surgery. In this study, we therefore retrospectively evaluated the perioperative factors, postoperative morbidity and mortality rate in patients with liver cirrhosis who had undergone cardiac surgery in our institute, and discussed the therapeutic strategy for perioperative management.

Patients and Methods

Of the 1374 patients who underwent cardiac surgery at Nagasaki University Hospital between May 1999 and December 2007, 21 patients with the diagnosis of liver cirrhosis were identified (1.5%). Table 1 shows the background of the patients. The patients consisted of 17 males and 4 females with a mean age of 66.0 ± 9.7 years (38-79 years). Liver cirrhosis was diagnosed in all patients based on characteristic morphological changes in the liver observed by abdominal ultrasonography, computed tomography, or magnetic resonance imaging.[6] Liver cirrhosis-related complications, such as ascites, gastroesophageal varices, and thrombocytopenia, were also taken into account. The severity of liver cirrhosis was determined according to the Child-Pugh classification.[7] Preoperative hepatic reserve was monitored using the 15-min indocyanine green retention rate (ICG R-15) and serum total bilirubin value. Preoperative cardiac function was evaluated by the New York Heart Association classification of cardiac performance, cardiac ultrasonography, and cardiac catheterization. The medical records of these patients were reviewed in detail with respect to the perioperative course.

The surgical procedures were as follows: Under general anesthesia, cardiopulmonary bypass (CPB) was initiated between the ascending aorta and either the right atrium or both cavae through median

Address correspondence: Kentaro Yamane M.D., Department of Cardiovascular Surgery, Nagasaki University Hospital, 1-7-1 Sakamoto, Nagasaki 852-8501 JAPAN

TEL: +81-(0)95-819-7307, FAX: +81-(0)95-819-7311, E-mail: kyamane777@yahoo.co.jp

Received April 2, 2008; Accepted May 2, 2008

Table 1. Patient Characteristics

		n=21	(%)
Gender			
	Female	4	(19%)
	Male	17	(81%)
Age (yr)		66.0±9.7	
NYHA class III and IV		16	(76%)
Ejection Fraction (%)		65±7	
Cardiac Diseases			
	CAD	7	(33%)
	CAD+MR	1	(5%)
	AR	2	(10%)
	ASR	2	(10%)
	AS	1	(5%)
	MR	1	(5%)
	MR+TR	2	(10%)
	TR+PS	1	(5%)
	IE+AR+MR	1	(5%)
	Constrictive Pericarditis	2	(10%)
	RA thrombus	1	(5%)
Comorbidities			
	Diabetes Mellitus	8	(38%)
	Hypertension	12	(57%)
	COPD	3	(14%)
	Prior stroke	7	(33%)
	Prior MI	2	(10%)
	Hyperlipidemia	2	(10%)
	CRI without hemodialysis	3	(14%)
	CRI with hemodialysis	4	(19%)

AR=aortic regurgitation, AS=aortic stenosis, ASR=aortic stenosis and regurgitation, CAD=coronary artery disease, COPD=chronic obstructive pulmonary disease, CRI=chronic renal insufficiency, IE=infective endocarditis, MI=myocardial infarction, MR=mitral regurgitation, NYHA=New York Heart Association, PS=pulmonary stenosis, RA=right atrial, TR=tricuspid regurgitation

sternotomy. In patients to whom conventional CPB was applied, roller pumps with a membrane oxygenator and a heparin-coating circuit were used. Initially, the dose of heparin was 200 units per body weight, and its administration was controlled to maintain the activated clotting time (ACT) at more than 400 sec. St. Thomas second solution (Miotecter®, Mochida Pharmaceutical Co. Ltd.) was used for myocardial protection. In 1 of the patients who underwent coronary artery bypass grafting (CABG), a mini-pump system using percutaneous cardiopulmonary support circuit was applied. According to a study of Takai et al., the mini-pump system consisted of a centrifugal pump, membrane oxygenator, and heparin-coating circuit with a soft reservoir.[8] The initial dose of heparin in the mini-pump system was 100 units per body weight and the ACT was targeted to more than 250 sec. In patients who underwent off-pump coronary artery bypass (OPCAB), the initial dose of heparin was 100 units per body weight. Blood transfusion was performed if necessary.

The operation time, CPB time, aortic clamp time, blood loss during surgery, chest tube output during the 24 hours after surgery, blood transfusion during and after surgery, and postoperative complications were recorded. Postoperative complications were classified into neurological (cerebral infarction, cerebral hemorrhage, and encephalopathy), respiratory (pneumonia, conditions requiring more than 48-hour mechanical ventilation, and those requiring tracheotomy), infection (deep sternal infection and sepsis), gastrointestinal (gastrointestinal hemorrhage and hepatic decompensation), renal (newly requiring hemodialysis), and hemorrhage (requiring reexploration for bleeding). The operative mortality was defined as death during a hospitalization or within 30 days after surgery. Metric parameters were expressed as the mean ± standard deviation or the median and range. The relationships between the perioperative parameters and postoperative complications were examined by non-parametric tests (Mann-Whitney U test and chi-square test). Statistical analysis was performed using SPSS version 11.0 (SPSS Inc., Chicago, IL, USA), and a value of $p<0.05$ was regarded as significant.

Results

As shown in Table 2, the causes of liver cirrhosis were viral hepatitis in 14 patients, alcohol in 2, autoimmune hepatitis in 1, congestive liver in 2, and unknown in 2. All patients with liver cirrhosis caused by viral hepatitis showed hepatitis C virus (HCV) positive. According to the Child-Pugh classification, 13 patients were in class A, 7 in class B, and 1 in class C. The preoperative ICG R-15 ranged from 7.0% to 37.0%, and it was 18.8 ± 10.0% in class A and 22.4 ± 9.8% in class B. In the 1 patient of class C, the preoperative ICG R-15 was not measured, because of emergency operation. The preoperative total bilirubin was 0.7 ± 0.4 mg/dL in class A, 1.5 ± 1.2 mg/dL in class B, and 1.0 mg/dL in class C. Gastroesophageal

Table 2. Preoperative liver profile and laboratory tests

		n=21	(%)
Etiology			
	Viral hepatitis	14	(67%)
	Alcohol	2	(10%)
	Autoimmune hepatitis	1	(5%)
	Congestive liver	2	(10%)
	Unknown	2	(10%)
Child-Pugh classification			
	Class A	13	(62%)
	Class B	7	(33%)
	Class C	1	(5%)
Ascites		8	(38%)
Gastric/Esophageal Varices		9	(43%)
Hepatocellular carcinoma		5	(24%)
Hemoglobin (g/dL)		10.9±2.1	
Platelet count ($x10^4/\mu L$)		11.5±6.0	
Total Bilirubin (mg/dL)		1.0±0.8	
Serum albumin (g/dL)		3.6±0.6	
Cholinesterase (U/L)		106±43	
Prothrombin time (%)		71±17	
ICG R-15 (%)		20.1±9.8	

ICG R-15=Indocyanine green retention rate 15 minutes after injection varices were detected in 9 patients, of whom 1 patient underwent balloon occluded retrograde transvenous obliteration before cardiac surgery.

Table 3 shows the outlines of cardiac surgery. CABG was performed in 7 patients, surgery for valvular disease in 10, simultaneous CABG and valvular procedure in 1, surgery for constrictive pericarditis in 2, and right atrial thrombectomy in 1. Of the patients who underwent CABG, OPCAB was performed in 3, and surgery using mini-pump system was performed in 1. Two patients underwent emergency operation. Reoperation was performed in 5 patients. The mean duration of operation was 278 ± 83 min, the mean CPB time 129 ± 53 min, and the mean aortic clamp time 75 ± 33 min. The mean blood loss within 24 hours after surgery was 751 ± 767 mL (122-3,227 mL). The blood transfusion during surgery was 5 ± 4 units for packed red blood cells, 5 ± 4 units for fresh frozen plasma, and 9 ± 9 units for platelets. The median mechanical ventilation time was 9.0 hours (3.0-82.0 hours). The median duration of intensive care unit stay and hospital stay after surgery were 3 days (1-23 days) and 20 days (14-167 days), respectively.

The postoperative complications include newly requiring hemodialysis in 2 patients, mechanical ventilation more than 48-hour in 2, mediastinitis in 1, and postoperative hepatic insufficiency in 1. The incidence of perioperative complications was 8% in class A, 29% in class B, and 100% in class C. The preoperative hemoglobin level was significantly lower in the patients with the postoperative complications (Table 4, p=0.009). There was one case of operative mortality. This patient, who had undergone mitral valve replacement and pericardiectomy, was in class B before the reoperation for the pericardiectomy. In this patient, the preoperative hemoglobin level was 9.2 g/dL, the operation time was 259 min, the CPB time was 152 min, and the blood loss during surgery was 3,360 mL. The preoperative total bilirubin was 4.0 mg/dL, which was highest in all patients. Postoperatively, the irreversible hepatic insufficiency was aggravated, requiring tracheotomy and continuous hemodiafiltration, and the patient died from multiple organ failure 23 days after surgery. Excluding this patient, the highest postoperative total bilirubin was 1.6 ± 0.8 mg/dL in class A, 2.2 ± 0.9 mg/dL in class B, and 2.1 mg/dL in class C. The surgical mortality rate was 0% in class A, 14% in class B, and 0% in class C.

Table 3. Operative data and clinical outcome

	Child-Pugh Classification		
	Class A	Class B	Class C
CABG			
On-pump	3	1	
Off-pump	3		
Valvular			
Aortic	4	1	
Mitral		1	
Multiple	1	2	1
CABG+Valvular		1	
Pericardiectomy	1	1	
Thrombectomy	1		
Emergent	1		1
Reoperation	2	3	
Operation time (min)	258±89	304±64	367
CPB time (min)	112±55	139±33	233
Cross clamp time (min)	67±25	69±9	173
Blood loss during operation (mL)	1004±1039	1382±1119	1060
Intraoperative blood transfusion			
Red blood cell (units)	5±3	6±6	8
Fresh frozen plasma (units)	4±4	7±5	10
Platelet (units)	6±9	13±10	20
ICU stay (days)	4.2±2.7	5.9±7.6	6
Morbidities			
New Dialysis	1	1	
Mechanical ventilation more than 48Hrs		1	1
Mediastinitis		1	
Hepatic decompensation		1	
In-hospital mortality (%)	0 (0%)	1 (14%)	0 (0%)

CABG=coronary artery bypass grafting, CPB=cardiopulmonary bypass, ICU=intensive care unit

Table 4. Possible predictive factors for postoperative morbidity in patients with cirrhosis undergoing cardiac surgery

	Post-operative complications		p value
	No (n=17)	Yes (n=4)	
Age (yr)	67.7±7.7	59.0±15.2	0.317
Ejection fraction (%)	65±7	64±8	0.829
Child-Pugh Classification			
Class A	12	1	
Class B	5	2	0.056
Class C		1	
(Class B + C)	5	3	0.133
Hemoglobin (g/dL)	11.5±2.0	8.7±0.8	0.009
Hemoglobin less than 10 g/dL	4 / 17	4 / 4	0.012
Platelet count (x104 /μL)	12.3±6.2	8.0±3.2	0.120
Total Bilirubin (mg/dL)	0.9±0.5	1.5±1.7	0.965
Total Bilirubin more than 1.5 mg/dL	3 / 17	1 / 4	0.602
Cholinesterase (U/L)	107±43	101±52	0.689
Serum albumin (g/dL)	3.7±0.5	3.3±0.7	0.275
Prothrombin time (%)	72±19	66±10	0.275
S-Cre more than 1.8 mg/dL	3 / 17	2 / 4	0.228
ICG R-15 (%)	21.4±9.7	13.3±9.3	0.171
Operation time (min)	281±85	269±82	0.897
CPB time (min)	125±50	145±71	0.362
Cross clamp time (min)	68±19	99±68	0.635
Reoperation	4 / 17	1 / 4	0.696
Beating Heart Surgery	5 / 17	1 / 4	0.684
Blood loss during operation (mL)	1109±956	1233±1469	0.829
Intraoperative blood transfusion			
Red blood cell (units)	4.2±3.2	8.8±6.4	0.120
Fresh frozen plasma (units)	4.4±3.9	8.5±4.4	0.144
Platelet (units)	8.2±9.5	12.5±9.6	0.462

CPB=cardiopulmonary bypass, NYHA=New York Heart Association, ICG R15=Indocyanine green retention rate 15 minutes after injection, S-Cre=serum creatinine

Discussion

With the development of surgical techniques, CPB equipment and perioperative management, less invasive surgical procedure has advanced in cardiac surgery. Application of surgical treatment has been spread in patients with severe comorbidities and the operative outcomes are improving.[9] Among patients with various preoperative complications, the morbidity and mortality rate following cardiac surgery are still high in patients with liver cirrhosis, and there is no evidence for the selection of patients, indication for surgical treatment, standard methods for preoperative evaluation of risks, or guidelines for perioperative management.[10] Since the prognosis of cardiac surgery is poor in patients with severe liver cirrhosis, reference of such patients to the surgical department may be often hesitated right from the start, resulting in the limited number of patients with liver cirrhosis who underwent cardiac surgery. Therefore, the number of studies on cardiac surgery performed in patients with liver cirrhosis is also limited. To improve the outcomes of surgical treatment for cardiac disease in patients with liver cirrhosis, we considered it important to accumulate data from a larger number of such patients and investigate their operative results.

There are various causes of liver cirrhosis, such as hepatitis viruses, alcohol abuse, autoimmune hepatitis, chronic cholestasis, metabolic disorders, and cardiogenic congestive liver. Since the hepatitis virus-infection rate is higher in Asia than in Europe and America,[11] the percentage of patients with liver cirrhosis in those who undergo cardiac surgery could be relatively high in the former. In our study, the percentage of liver cirrhosis caused by hepatitis viruses was 66.7%, and all patients showed HCV positive. Filsoufi et al. reported that the percentage of patients with liver cirrhosis in those who underwent cardiac surgery was 0.5%,[12] while in our study, it was 3-fold higher (1.5%).

Table 5 shows the studies on cardiac surgery performed in patients with liver cirrhosis (more than 10 patients).[1-5,12-14] The mortality rate was 0-10% in class A and 18-80% in class B, according to the Child-Pugh classification. In these studies, cardiac surgery was performed in 11 patient of Child-Pugh class C, and there were 7 operative deaths. The morbidity rate was 15-100% in class A, 33-100% in class B, and 100% in class C. In our study, the mortality rate was 0% in class A, 14% in class B, and 0% in class C. The

Table 5. Clinical Studies in patients with cirrhosis undergoing cardiac surgery

Author	Year	CPB use	n	Number of patients			Mortality (%)			Morbidity (%)		
				Child-Pugh Class			Child-Pugh Class			Child-Pugh Class		
				A	B	C	A	B	C	A	B	C
Klemperer et al	1998	yes	13	8	5		0	80		25	100	
Bizouarn et al	1999	yes	12	10	2		0	50		50	100	
Kaplan et al	2002	yes	8	2	6		0	50		100	100	
		no	2	2			0			100		
Hayashida et al	2004	yes	15	10	4	1	0	50	100	40	100	100
		no	3		3			0			33	
Suman et al	2004	yes	44	31	12	1	3	41	100	10	66	100
Lin et al	2005	yes	16	11	4	1	9	0	0	45	75	100
		no	2	2			0			0		
An et al	2007	yes	24	17	6	1	6	67	100	53	100	100
Filsoufi et al	2007	yes	18	10	11	6	10	18	67	20	55	100
		no	9									
Present study	2008	yes	18	10	7	1	0	14	0	8	29	100
		no	3	3			0			0		

CPB=cardiopulmonary bypass

morbidity rate was 8% in class A, 29% in class B, and 100% in class C. We encountered 1 patient in class C, who underwent emergency surgery for critical condition of infective endocarditis of the aortic and mitral valves after renal transplantation for chronic renal insufficiency. Although long-term postoperative mechanical ventilation was required, this patient was discharged after relief without other complications. Since the surgical mortality rate in class C is very high, the application of cardiac surgery to patients, except for those who cannot be treated for critical condition other than surgical treatment, should be evaluated with caution. In the patients shown in Table 5, OPCAB was performed in 10 patients, including our 3 patients, no surgical mortality was observed. In our 3 patients, the postoperative courses were satisfactory, indicating that OPCAB is useful for the coronary revascularization in patients with liver cirrhosis.[15,16]

The severity of liver cirrhosis is generally evaluated using the Child-Pugh classification.[7] In this classification, ascites, psychoneurotic symptoms (hepatic encephalopathy), serum bilirubin, albumin, and prothrombin time were scored in 1 to 3 points, and total scores of 5-6, 7-9, and more than 10 points are defined as classes A, B, and C, respectively. This classification method is simple to conduct, and the correlations between the Child-Pugh class and surgical mortality or the incidence of complications are considered high.[12] In cardiac surgery, the evaluation of patients with liver cirrhosis is often performed using the Child-Pugh classification.[1,3] The model for end-stage liver diseases (MELD) score is also often used for the postoperative prediction of transjugular intrahepatic portosystemic shunt treatment and liver transplantation.[17] Suman et al. reported that the MELD score was useful for the prediction of mortality and hepatic insufficiency after cardiac surgery in patients with liver cirrhosis.[14] On the other hand, Filsoufi et al. reported that the Child-Pugh classification was more useful for the prediction of hospital mortality than the MELD score.[12] As the prognosis-determining factors for surgical mortality, the preoperative serum total bilirubin, cholinesterase, and CPB time have been reported.[5,18] In the present study, only 1 patient died, of whom the preoperative total bilirubin was highest. The ICG R-15 is often used for the evaluation of preoperative hepatic reserve,[19] but it was not significantly correlated with postoperative complications in our study. It has been reported that histological findings in liver cirrhosis were sometimes not correlated with the ICG R-15 values in the presence of shunts.[20] Therefore, it is necessary to evaluate the relationship between the ICG R-15 and surgical mortality or the prognosis by accumulating data from a larger number of patients. Takami et al. has reported the usefulness of asialoscintigraphy for the evaluation of hepatic reserve in such patient group undergoing cardiac surgery.[21]

In patients with liver cirrhosis, postoperative complications are caused by liver cirrhosis or its related complications. Briefly, the proliferation of the fibrous partition and connective tissues in the liver causes changes in hepatic vascular resistance, resulting in portal hypertension. Portal hypertension causes gastroesophageal varices, gastrointestinal hemorrhage, fluid retention tendency, such as pleural effusion and ascites, hepatic encephalopathy induced by hyperammonemia, and thrombocytopenia by hypersplenism.[10] Decreases in hepatic cells cause the reduction of protein-synthesizing ability and abnormalities in the bilirubin metabolism, resulting in hypoalbuminemia, coagulopathy, and hyperbilirubinemia. In very advanced hepatic dysfunction, fibrinolytic capacity is enhanced, and severe hemorrhage is often induced synergetically by thrombocytopenia and coagulopathy.[22] In our patients with postoperative complications, the preoperative hemoglobin level was significantly low. It has been reported that a higher hematocrit value is advantageous for hepatic blood flow during extracorporeal circulation, and the correction of the hemoglobin level is important.[23] Klemperer et al. has reported that blood transfusion was required for cardiac surgery in patients with liver cirrhosis at 3-fold higher rate than for patients without cirrhosis.[3] Therefore, it is important to prepare a sufficient amount of blood for transfusion, but excessive blood transfusion could further aggravate the hepatic function. OPCAB tends to require a smaller amount of blood for transfusion than surgery under conventional CPB, indicating that this method is advantageous for the myocardial revascularization in patients with liver cirrhosis.[24] No postoperative complications were observed in patients who had undergone CABG using off-pump or mini-pump procedure in our study. Even though there still remains the possibility that well preserved preoperative hemoglobin level might explain satisfactory postoperative course, because of a smaller dose of heparin than that for conventional CBP and smaller effect on the coagulation and fibrinolytic systems,[8] we thought these methods are very useful in such patient group. The mini-pump system can be applied to surgical treatment for valvular diseases, and the release of inflammatory cytokines or vascular reactants is lower in this system than in conventional CPB, indicating that this system could improve operative results in patients with liver cirrhosis.[25]

Postoperaive infection and fluid-retention tendency are also major concern in this patient group.[13] In our study, we encountered 1 patient with postoperative mediastinitis in class B. This patient had been administered steroids for the treatment of autoimmune hepatitis and systemic lupus erythematosus. In patients with liver cirrhosis, it is necessary to improve nutritional conditions before surgery, reduce the CPB time, and carefully perform hemostasis to avoid reexploration. There are perioperative risks, such as hypoalbuminemia, ascites caused by portal hypertension, pleural effusion or pericardial fluid, and fluid retention in a third space.[26] These symptoms cause difficulties in fluid control and respiratory management. The advancement of hepatic dysfunction causes hepatorenal syndrome, and further fluid retention, sodium retention, and renal dysfunction could be induced.[14] Atrial natriuretic peptides are reported to be useful for perioperative fluid balance control in patients with liver cirrhosis.[27] Among problematic postoperative complications in patients with liver cirrhosis, factors induced by altered liver function, such as bleeding tendency, susceptibility to infection and hepatorenal syndrome is more responsible for poor operative results than postoperative cardiac dysfunction.[12] To improve the operative outcome of these patients, overcoming these complications is mandatory.

There are several limitations in this study. Since this study was retrospectively performed, the characteristics of such a method must be taken into account and any conclusions should be limited in their implication. Since patients with liver cirrhosis, in whom risks for surgical treatment are judged unacceptably high by physicians, are not referred for cardiac surgery to the surgical department, such patients may not be included. Although the number of patients in our study was relatively large compared to past studies, it was still insufficient for analyzing the relationship between preoperative factors and complications or surgical mortality.

In conclusion, our findings indicate acceptable mortality rate in each severity of liver cirrhosis compared to previous reports. However, the incidence of severe complications, such as prolonged ventilation, mediastinitis and irreversible hepatic insufficiency was still high and problematic in class B and class C patients. In patients with severe liver cirrhosis, the preoperative hemoglobin level and total bilirubin value should be controlled meticulously to improve surgical outcome. With the increase in the application of less invasive cardiac surgery, such as the use of mini-pump system or off-pump procedure, surgical outcomes will be improved in patients with severe liver disease.

References

1. Bizouarn P, Ausseur A, Desseigne P, Le Teurnier Y, Nougarede B, Train M et al. Early and late outcome after elective cardiac surgery in patients with cirrhosis. *Ann Thorac Surg* 67: 1334-1338, 1999
2. Hayashida N, Shoujima T, Teshima H, Yokokura Y, Takagi K, Tomoeda H et al. Clinical outcome after cardiac operations in patients with cirrhosis. *Ann Thorac Surg* 77: 500-505, 2004
3. Klemperer JD, Ko W, Krieger KH, Connolly M, Rosengart TK, Altorki NK et al. Cardiac operations in patients with cirrhosis. *Ann Thorac Surg* 65: 85-87, 1998
4. Lin CH, Lin FY, Wang SS, Yu HY, Hsu RB. Cardiac surgery in patients with liver cirrhosis. *Ann Thorac Surg* 79: 1551-1554, 2005
5. An Y, Xiao YB, Zhong QJ. Open-heart surgery in patients with liver cirrhosis. *Eur J Cardiothorac Surg* 31: 1094-1098, 2007
6. Brown JJ, Naylor MJ, Yagan N. Imaging of hepatic cirrhosis. *Radiology* 202: 1-16, 1997
7. Pugh RN, Murray-Lyon IM, Dawson JL, Pietroni MC, Williams R. Transection of the oesophagus for bleeding oesophageal varices. *Br J Surg* 60: 646-649, 1973
8. Takai H, Eishi K, Yamachika S, Hazama S, Nishi K, Ariyoshi T et al. The efficacy of low prime volume completely closed cardiopulmonary bypass in coronary artery revascularization. *Ann Thorac Cardiovasc Surg* 10: 178-182, 2004
9. Gehlot A, Mullany CJ, Ilstrup D, Schaff HV, Orzulak TA, Morris JJ et al. Aortic valve replacement in patients aged eighty years and older: early and long-term results. *J Thorac Cardiovasc Surg* 111: 1026-36, 1996
10. Hayashida N, Aoyagi S. Cardiac operations in cirrhotic patients. *Ann Thorac Cardiovasc Surg* 10: 140-147, 2004
11. McCaughan GW. Asian perspectives on viral hepatitis: hepatitis C virus infection. *J Gastroenterol Hepatol* 15 Suppl: G90-93, 2000
12. Filsoufi F, Salzberg SP, Rahmanian PB, Schiano TD, Elsiesy H, Squire A et al. Early and late outcome of cardiac surgery in patients with liver cirrhosis. *Liver Transpl* 13: 990-995, 2007
13. Kaplan M, Cimen S, Kut MS, Demirtas MM. Cardiac operations for patients with chronic liver disease. *Heart Surg Forum* 5: 60-65, 2002
14. Suman A, Barnes DS, Zein NN, Levinthal GN, Connor JT, Carey WD. Predicting outcome after cardiac surgery in patients with cirrhosis: a comparison of Child-Pugh and MELD scores. *Clin Gastroenterol Hepatol* 2: 719-723, 2004
15. Carr C, Desai J. OPCAB surgery in a cirrhotic hepatocellular carcinoma patient awaiting liver transplant. *Ann Thorac Surg* 78: 1460-1462, 2004
16. Yamamoto T, Takazawa K, Hariya A, Ishikawa N, Dohi S, Matsushita S. Off-pump coronary artery bypass grafting in a patient with liver cirrhosis. *Jpn J Thorac Cardiovasc Surg* 50: 526-529, 2002
17. Schepke M, Roth F, Fimmers R, Brensing KA, Sudhop T, Schild HH et al. Comparison of MELD, Child-Pugh, and Emory model for the prediction of survival in patients undergoing transjugular intrahepatic portosystemic shunting. *Am J Gastroenterol* 98: 1167-1174, 2003
18. Hirata N, Sawa Y, Matsuda H. Predictive value of preoperative serum cholinesterase concentration in patients with liver dysfunction undergoing cardiac surgery. *J Card Surg* 14: 172-177, 1999
19. Gadano A, Hadengue A, Vachiery F, Moreau R, Sogni P, Soupison T et al. Relationship between hepatic blood flow, liver tests, haemodynamic values and clinical characteristics in patients with chronic liver disease. *J Gastroenterol Hepatol* 12: 167-171, 1997
20. Nanashima A, Yamaguchi H, Shibasaki S, Morino S, Ide N, Takeshita H et al. Relationship between indocyanine green test and technetium-99m galactosyl serum albumin scintigraphy in patients scheduled for hepatectomy: Clinical evaluation and patient outcome. *Hepatol Res* 28: 184-190, 2004
21. Takami Y, Masumoto H. Preoperative evaluation using asialoscintigraphy in patients undergoing cardiac surgery with noncardiac liver cirrhosis. *Jpn J Thorac Cardiovasc Surg* 54: 463-468, 2006

22. Michalopoulos A, Alivizatos P, Geroulanos S. Hepatic dysfunction following cardiac surgery: determinants and consequences. *Hepatogastroenterology* 44: 779-783, 1997
23. Nollert G, Sperling J, Sakamoto T, Jaeger BR, Jonas RA. Higher hematocrit improves liver blood flow and metabolism during cardiopulmonary bypass in piglets. *Thorac Cardiovasc Surg* 49: 226-230, 2001
24. Ben Ari A, Elinav E, Elami A, Matot I. Off-pump coronary artery bypass grafting in a patient with Child class C liver cirrhosis awaiting liver transplantation. *Br J Anaesth* 97: 468-472, 2006
25. Takai H, Eishi K, Yamachika S, Hazama S, Ariyoshi T, Nishi K. Demonstration and operative influence of low prime volume closed pump. *Asian Cardiovasc Thorac Ann* 13: 65-69, 2005
26. Gentilini P, La Villa G, Romanelli RG, Foschi M, Laffi G. Pathogenesis and treatment of ascites in hepatic cirrhosis. *Cardiology* 84 Suppl 2: 68-79, 1994
27. Carstens J, Greisen J, Jensen KT, Vilstrup H, Pedersen EB. Renal effects of a urodilatin infusion in patients with liver cirrhosis, with and without ascites. *J Am Soc Nephrol* 9: 1489-1498, 1998