Revascularization in patients with severe left ventricular impairment who have ischemic heart disease

Selim Erentürk, MD, PhD, *Cenk E. Yıldız,* MD, *Murat Gulbaran,* MD, PhD.

ABSTRACT

Objectives: To assess the effect of coronary bypass grafting on left ventricular (LV) function, exercise capacity and symptom profile in patients with LV impairment and retrospectively evaluate the role of the different factors affecting LV.

Methods: A total of 45 patients (33 men, 12 women, mean age 63.49 ± 7.38 years) with LV ejection fraction of less than 0.32 were admitted to the Istanbul University, Cardiology Institute, Istanbul, Turkey between January 2001 to June 2003 for coronary bypass operation. Preoperative and postoperative wall motion, functional class (New York Heart Association) and risk factors were analyzed.

Results: We had one perioperative mortality (2.2%) and 2 early postoperative mortality (4.4%) due to poor cardiac function. There was a significant increase in the mean LV ejection fraction from 26.64 ± 5.17 to 32.98 ± 6.38 ($p<0.001$) postoperatively. In this group the mean New York Heart Association grade improved from 2.07 ± 0.76 to 1.5 ± 0.79 ($p<0.001$). Preoperative functional class, congestive heart failure, arrhythmia, age, pre/postoperative complications were the main predictors of poor outcome following surgical revascularization for ischemic cardiomyopathy.

Conclusion: In patients with severe LV impairment with myocardial hibernation, coronary artery bypass grafting improves both global and regional LV function and symptom profile. We therefore, recommend a coronary artery bypass grafting as an alternative to orthotopic heart transplantation whenever myocardial viability are documented.

Saudi Med J 2007; Vol. 28 (1): 54-59

From the Department of Cardiovascular Surgery (Erentürk), Department of Cardiovascular (Yıldız), Department of Cardiology (Gulbaran), Istanbul University, Cardiology Institute, Istanbul, Turkey.

Received 7th December 2005. Accepted 30th August 2006.

Address correspondence and reprint request to: Prof. Dr. Selim Erentürk, I.U. Tıp Fakültesi, Kalp Damar Cerrahisi A.B. Dalı, Capa, Istanbul. Tel. +542 3433847. E-mail: selimerenturk@superonline.com

Burch and Harb[1] defined ischemic cardiomyopathy (CMP) after observations of coronary artery disease during the anatomicopathologic studies on dilated cardiomyopathy cases. In several publications, it is also reported that the clinical progress of the ischemic CMP is worst when compared with other types of myopathy.[2-4] It has been shown in some studies such as Coronary Artery Surgery Study (CASS)[5] that surgical revascularization provides better long-term results than medical therapies.[3,4,6-8] With a medical therapy, the life expectancy is very limited and patients are usually lost due to cardiac causes.[7-9] In those cases, even though orthotopic cardiac transplantation is an effective treatment, the low number of donors limits the procedure. Furthermore, the transplantation itself has very high risks.[2] Transmyocardial laser revascularization, partial ventriculectomy, cardiomyoplasty and ventricular assist devices provide some palliative cure for short terms, but they have high mortality risks. There are still continuing studies regarding genetic applications, tissue implantation, angiogenesis and xeno-transplantations.

The contractile function of a ventricle is related to states of being the myocardium hibernated or stunned following reperfusion. Hibernation is defined as the decrease of the whole ventricular function due to reduced blood flow to myocardium.[10] Medical therapy of myocardial hibernation does not reverse symptoms and does not increase the performance of the deteriorated left ventricle more than revascularization.[3] Assessment of the viability of the myocardium has a key role in the decision for surgical revascularization and hence, in the success of surgery. However, even if myocardial hibernation is shown, medical and surgical therapy has higher mortality rate in ischemic CMP.[3,4] Revascularization of ischemic CMP cases has lower mortality rates whenever cases with very low left ventricular ejection fraction (LVEF) or with very reduced myocardial viability can be excluded for heart transplantation.[3,6,11,12]

Methods. The study included 45 cases (33 males, 12 females) whose revascularization have been established by coronary artery bypass graft (CABG) operation between January 2001 and June 2003 at the Istanbul University, Cardiology Institute, Istanbul, Turkey. Follow-up of the patients was one year. We performed echocardiography for the patients preoperatively and then postoperatively on the first and third month. The preoperative LVEF were between 24 - 30% in 33 cases, between 20 - 24% in 8 and less than 20% in 4 cases. The mean age was 63.49 ± 7.38 years (range, 40-74 years) (**Table 1**). The criteria for the indication of operation were determined as detection of myocardial viability by thallium-201 scan test and if necessary (if patients myocardium has limited viability by thallium test and very low ejection fraction) by positron emission tomography. Coronary stenosis more than 70% and angiographically available distal coronary arteries had to be revascularized.

We compared the parametric values between the ex-cases and living cases with the T-test and the nonparametric values with the Mann-Whitney test (**Tables 3 & 4**). We analyzed preoperative and postoperative echocardiographic LVEF, New York Heart Association (NYHA) and grade and inotropic support data of the patients and the significancy with the paired T test (**Table 5a**). We used chi-square test and logistic regression tests for the relationship of the data between the mortality and the significancy (**Table 6**).

Table 1 - Patients characteristics.

Variables	Range	Mean ± SD	
Age	(40-74)	63.49 ± 7.38	year
No. of grafts	(1-5)	3.29 ± 1.10	
Preop Echo	(20-35)	26.64 ± 5.17	%
CPB	(70-424)	167.76 ± 74.50	min
Cross clamp time	(37-180)	89.04 ± 30.83	min
Preopera dopa	(6.0-16.0)	7.351 ± 5.947	mic/kg/min
Preop dbtx	(0-15)	6.831 ± 4.305	mic/kg/min
Preop adrenalin	(0-08)	0.0444 ± 0.011	mic/kg/min
ICU days	(3-14)	7.48 ± 2.64	day
Postop dopa	(5-12)	6.86 ± 2.32	mic/kg/min
Postop dbtx	(0-16)	7.14 ± 5.09	mic/kg/min
Postop adrenalin	(0.0-10)	0.035 ± 0.017	mic/kg/min
Hospital days	(8-18)	12.08 ± 2.82	day
Postop Echocard	(20-45)	32.98 ± 5.95	%

CPB - cardiopulmonary by-pass time, dbtx - dobutrex

Table 2 - Frequency table.

Variables		Frequency (%)	
Gender	Male	33	(73.3)
	Female	12	(26.7)
Preop MI	Anterior	19	(42.2)
	Inferior	9	(20)
	Antsept	5	(11.1)
	Ant-inf	12	(26.7)
Preop risk	No	15	(33.3)
	Smoke	28	(62.2)
	DM	2	(4.4)
NYHA	1	9	(20)
	2	26	(57.8)
	3	8	(17.8)
	4	2	(4.4)
IABP	No	42	(93.3)
	Yes	3	(6.7)
No of grafts	1 ves	3	(6.7)
	2 ves	5	(11.1)
	3 ves	21	(46.7)
	4 ves	8	(17.8)
	5 ves	8	(17.8)
Arrhythmia	Yes	29	(65.9)
	No	15	(34.1)
Complication	No	36	(81.8)
	Cardiac	5	(11.4)
	Non-cardiac	3	(6.8)
Card result	Good	30	(68.2)
	Mid	6	(13.6)
	Bad	8	(18.2)
Result	Good	31	(68.9)
	Mid	6	(13.3)
	Ex	8	(17.8)

MI - myocardial infarction, NYHA - New York Heart Association, IABP - intra-aortic balloon pump, DM - diabetes mellitus, Preop - preoperative, Card cardiac

Table 3 - T-test for equality of means between exitus and live patients (age, preoperative echocardiography, inotropic support).

Variables		t	*p*-value	Mean difference	Standard error difference
Age	Equal variances Assumed	2.965	0.005	7.98	2.692
	Equal variances Not assumed	4.223	0.001	7.98	1.89
Echo Preop	Equal variances Assumed	-1.148	0.257	-2.3	2.007
	Equal variances Not assumed	-1.286	0.223	-2.3	1.791
Inotrop Supp	Equal variances Assumed	15.091	0.0001	5.77	0.382
	Equal variances Not assumed	17.703	0.0001	5.77	0.326

Table 4 - Mann-Whitney test between exitus and live patients [CCT - circulation time (minute), ACT - aortic clamp time (minute), inotropic medicaments (microgram/kg/min), ICU - intensive care unit room stay time (day)]. Group variable: mortality.

Variables	Mann-Whitney U	Wilcoxon W	Asym Sig (*p*-value)
CCT	88,500	791,500	0.077
ACT	125,000	828,000	0.495
Dopamin	130,000	833,000	0.547
Dobutamin	80,500	704,500	0.038
Adrenalin	26,000	729,000	0.0001
ICU stay	26,500	729,500	0.0001

Table 5a - Paired samples test statistics (between preoperative and postoperative data).

Variables		Mean	Standard Deviation	Standard error of mean
Pair 1	Echo 1	26.64	5.17	0.83
Pair 2	Echo 2	32.98	5.95	0.93
Pair 1	NYHA	2.07	0.76	0.11
Pair 2	NYHA	1.5	0.79	0.12
Pair 1	Dopa	7.351	5.947	0.561
Pair 2	Dopa	6.86	2.32	0.35
Pair 1	Dbtx	6.647	4.169	0.629
Pair 2	Dbtx	7.14	5.09	0.77
Pair 1	Adrena	0.0444	0.011	0.0017
Pair 2	Adrena	0.0357	0.017	0.0041

Pair 1 - preoperative, pair 2 - postoperative
NYHA - New York Heart Association
Dbtx - dobutrex, Adrena - Adrenalin

Table 5b - Paired samples correlations. Difference between pre- and postoperative ventricular performance and inotropic medications.

Pair	Mean ± SD	T	*p*-value
Preop - Postop Echo	-6.34 ± 6.81	-5.743	0.0001*
Pre - post NYHA	0.57 ± 1.11	3.401	0.001*
Pre - post dopa	1.491 ± 8.486	1.165	0.250
Preop - postop DBTX	-0.493 ± 3.145	-1.040	0.304
Preop - postop adrenalin	0.009 ± 3.145	-2.691	0.010*

**p*-value is significant
Echo - echocardiography, preop - preoperative, postop - postoperative, NYHA - New York Heart Association, DBTX - dobutrex

Table 6 - Chi-square tests (between exitus and live patients).

Variables	Pearson Chi-Square		Fisher's Exact Test
	Value	Asymp. Sig.	Exact Significance (p-value)
Gender	0.999	0.318	0.419
Pre MI (less of ant-inf)	12.234	0.007	0.0001*
Risk factors	0.618	0.432	0.452
Urgency	3.441	0.064	0.085
IABP	5.256	0.022	0.077
Preoperative cardiac performance (echocardiography, angiography)	37.459	0.001	0.0001*
Complications	25.520	0.000	0.0001*
Bypass graft number (1-2 of more)	0.347	0.556	0.618

**p*-value is significant
Asymp. Sig - asymptomatic significance, MI - myocardial infarction, IABP - intra-aortic balloon pump

The Spearman test and the Pearson correlation test was used in our patients as the correlation tests (**Table 7**).

Results. Thirty-four cases (75.6%) were operated in elective conditions and 11 were urgently taken for operation (24.4%). Left ventricular aneurysmectomy (LVA) was applied to 4 cases and aortic valve replacement (AVR) was applied to one case in addition to CABG. Extra-corporal circulation (ECC) was necessary for 3 cases for long term and intra aortic balloon pump (IABP) support was required in one case. Various arrhythmias were detected in 11 patients (24.4%). Inotropic support was extended for 12 cases in surgical intensive care unit. Perioperative mortality was only one (2.2%). Early postoperative mortality was 2 (4.4%) due to lower cardiac function (4.4%). A patient died in the second week due to pulmonary laceration and hemorrhage, another patient died in the 23rd day post-operatively due to low cardiac performance and sepsis (2.2%), and one patient was lost due to cerebrovascular accident (CVA) (2.2%). Two patients were lost (one of them due to the cardiac reasons) in the late stage (4.4%). Total mortality was 8/45 (17.77%) (**Table 2**).

The ex-cases evaluated with the T-test included older age patients, which needed higher inotropic support. Furthermore, Mann-Whitney test showed that the ex-cases stayed a longer period in the intensive care unit (**Tables 3 & 4**).

The relationship between mortality and low cardiac performance of the patients and complications were significantly meaningful and were not significant between gender, preoperative risk factors, urgency, use of the IABP and numbers of the bypass grafts according to chi-square test (**Table 4**). Analyzing with the logistic regression test could not be used due to low number of cases. A significant increase in exercise capacity and improvement in LVEF as well as in their clinical status were observed with the paired samples T-test (**Table 5b**).

There was a significant relationship between the cardiopulmonary bypass time and the aortic clamp time, postoperative cardiac performance, inotropic support, hospitalization time using the Pearson correlation test (**Table 7**). The relationships between mortality and complications and the cardiac performance was highly significant and between age, bypass graft number, arrhythmia and usage of the IABP had a low significance and also between age and complication, anterior-inferior MI and for capacity, complication and arrhythmia and lastly arrhythmia and IABP have been evaluated as highly related due to Spearman test.

Discussion. There are different treatment modalities for ischemic CMP. However, there is a consensus on the obvious benefit of myocardial revascularization, that the contraction of left ventricle, and changes of functional capacity are related to the myocardial hibernation.[2-6,9-11] Several diagnostic methods can be used for investigation of hibernation: 1. Decreased MVO_2 Nitroglycerin (or Isosorbide dinitrate) ventriculogram, 2. Inotropic stimulation, 3. Demonstration of defect with stress induction such as perfusion thallium-201-scan or stress echocardiography, 4. positron emission tomography (PET).

For investigation of viability, control of wall motion with 2-D echocardiography and thallium-201 perfusion scan are easy methods that we also perform. On the other hand, the golden standard for the detection

Table 7 - Pearson correlation test.

Variables	Age	Echo1	CCT	ACT	Dopa1	Dbtx1	Adr 1	ICU	Dopa 2	Dbtx2	Adr2	dep	Echo2
Age Pearson Sig (*p*)	1												
Echo1	.072 .637	1											
CCT	.153 .316	-.006 .966	1										
ACT	.072 .639	.046 .762	.897** .000	1									
Dopa1	.242 .109	-.380* .010	.019 .902	-.060 .693	1								
Dbtx1	-.005 .975	-.327* .028	.190 .211	.182 .233	.355* .017	1							
Adr1	.216 .155	-.197 .194	.361* .015	.269 .074	.346* .020	.366* .013	1						
ICU	-.054 .727	-.260 .089	.145 .346	.192 .212	.178 .246	.377* .012	.297 .050	1					
Dopa2	.36* .016	-.151 .329	.311* .040	.157 .310	.089 .565	.276 .069	.297 .051	.574** .000	1				
Dbtx2	.098 .526	-.220 .151	.293 .054	.249 .103	.047 .761	.787** .000	.299* .049	.508** .000	.713** .000	1			
Adr2	.250 .101	-.238 .120	.381* .011	.227- .139	.032 .836	.273 .073	.592** .000	.369* .014	.703** .000	.561** .000	1		
Dep	-.146 .390	-.296 .075	.271 .104	.325* .050	.094 .580	.431** .008	.340* .040	.580** .000	.453** .005	.505** .001	.372* .023	1	
Echo2	-.054 .749	.336* .039	-.566** .000	-.56** .000	-.097 .563	-.384* .017	-.47** .003	-.380* .019	-.330* .043	-.420** .009	-.433** .007	-.528** .001	1

*Correlation is significant at the 0.05 level (2-tailed)**Correlation is significant at the level 0.01 (2-tailed)
Sig - significant, CCT - circulation time, ACT - aortic clamp time, Dbtx - Dobutrex, ICU - intensive care unit, Dopa - dopamine, dep - hospitalization days

of myocardial viability is the PET. Bonow et al[13] has shown that the myocardial area that was observed with irreversible perfusion defected by thallium scintigraphy was metabolically active and alive in PET. The sensitivity of Thallium-201 (TI-201) SPECT was reported as 78%.[3]

There are several opinions regarding whether the LVEF is a standpoint for surgery. In a study from the Duke University, it has been proven that there is no parallel relationship between the functional status and the LVEF.[14] Isolated LVEF does not indicate exactly the left ventricular function. Ventricular dilatation may also be developed as a compensatory mechanism due to reduced LVEF.[2] From this point of view, there is a widely accepted opinion, which states that LVEF should be supported with investigations that determine the viable status of myocardium.[2,15] Louie et al[16] are focused on the measurements of end diastolic diameter by means of echocardiography as a definitive indicator.

The benefit of myocardial revascularization is limited in cases with LVEF less than 20%. Some authors evaluate these cases as candidates of orthotopic cardiac transplantation while others are distinguishing them as candidates for either to cardiac transplantation provided that viability is not detected by PET or to CABG.[2] Some authors report that examination of wall thickness and the viability during bypass operation is important for decision making whether to perform CABG or partial ventriculotomy.[4] If only LVEF is considered as an indication for operation, the rate of mortality may vary between 1.6%, 12% and even 37%.[17] This can be misleading in evaluating the benefit of surgical revascularization. Therefore, for the benefit of surgery, hemodynamic studies should be precisely performed and viability should be investigated carefully before the operation. In our cases, slight significant correlation was determined between the preoperative LVEF, and morbidity and mortality when the Spearman tests were used for that purpose (p=0.047).

For these cases, there are different opinions for the indication of CABG. Some authors claim that finding 2 or more vessels appropriate for bypass and detecting the viability in the akinetic or hypokinetic areas fulfills the criteria for operation.[2] On the other hand, some do not evaluate cases having congestive heart failure (CHF) with low LVEF as candidates for CABG.[18] The existence of documentable viable myocardium is the common justification for the revascularization operation. Besides, a suitable coronary tree must exist for operation. These are our criteria for the CABG operation, too.

After revascularization in ischemic CMP patients, global and regional left ventricular performance and symptom profile are improved. Middleborough et al[4] reported that in patients with a preoperative ejection fraction of 18%, the CSS angina class has changed from 3.2 ± 1.0 µ1 to 1.5 ± 0.8. Similarly, Gunning et al[3] reported that preoperative NYHA functional degree has changed from 2.7 ± 0.5 to 1.4 ± 0.8. Paolini et al[19] reported that postoperative NYHA effort capacity is improved only in cases, where viability could be shown by PET. Di Carli et al[20] reported that NYHA class may improve in cases where viability has been shown by PET. However, in this study 10 of the 50 cases which were followed only medically, died in 13.6 months.[20] In our cases, we observed that the preoperative symptoms did improve after the surgical revascularization. Effort capacity has changed from 2.07 ± 0.76 to 1.50 ± 0.79 according to NYHA classification (p<0.001) (**Table 5b**).

There are several studies, which prove that surgical revascularization can improve LVEF positively. Rogosta et al[21] has shown that LVEF being 29% in preoperative has changed to 41% in the postoperative period in cases where hibernation was detected in preoperative Tl-201 investigation. Gunning et al[3] has shown that LVEF had been raised from 24 to 29.7% in surgery group, whereas it has fallen from 25.7 to 20.6% in medical therapy group in the same period of time. Salati et al[6] has shown that LVEF has been raised from 25% ± 0.5 to 31% ± 0.70 (p<0.001) and that the end diastolic pressure of LV has fallen from 23 ± 1.0 mmHg to 16.5 ± 9 mmHg. Dreyfus et al[2] has shown that LVEF has increased from 0.23% ± 0.06 to 0.39% ± 0.13 postoperatively. In our study, the LVEF being 26.6% ± 5.17 before operation, has risen to 32.98% ± 6.45 following revascularization and we found that significant via paired-samples test (p<0.001) (**Table 5b**). Rahimtoola[10] claims that the contraction of the left ventricle can be improved following the operation, however complete improvement occurs after 3 to 12 months. In our cases, even though the need for inotropic support was increased in the early postoperative period, a significant rise in the LVEF was detected in their outpatient examinations.

In several studies, a relationship between the kind of operation and mortality has been sought and the mortality rate was lower for patients who were operated in elective conditions.[2,5,6,22] In our study, a meaningful correlation exists between emergent operations and mortality and the need for IABP.

Arrhythmia is an important risk factor for mortality.[2,23] In our study, there was a direct correlation between arrhythmia and mortality (p<0.0001) (**Table 6**), (r=0.539 Spearman test).

We evaluated that pre and postoperative complications were important factors in the mortality and especially in deaths due to non-cardiac reasons. Also gender, preoperative risk factors, number of the grafts, urgency, effort capacity did not influence mortality.

Nowadays, in suitable cases with ischemic CMP it is preferred to perform a CABG-operation on a beating heart, so that the heart can be protected against global ischemic damage and against some harmful effects of the heart-lung-pump.

Patients with ischemic and severe CMP have limited life span and quality of life through medical therapy. Although there are difficulties with donors and postoperative maintenance, cardiac transplantation is another option. Whenever taken under elective conditions to bypass operation, cases with proven viability and appropriate coronary vessels to bypass myocardial revascularization should be the preferred option with acceptable morbidity and mortality rates.

References

1. Burch GE, Harb JM. Ischaemic cardiomyopathy. ***Am Heart J*** 1972; 83: 340-350.
2. Dreyfus GD, Duboc D, Blasco A, Vigoni F, Dubois C, Brodaty D, et al. Myocardial viability assessment in ischemic cardiomyopathy: Benefits of coronary revascularization. ***Ann Thorac Surg*** 1994; 57: 1402-1408.
3. Gunning MG, Chua TP, Harrington D, Knight CS, Burran E, Pennel DJ et al. Hibernating myocardium clinical and functional response to revascularization. ***Eur J Cardio-Thorac Surg*** 1997; 11: 1105-1112.
4. Middleborough LL, Carson S, Tamariz M, Ivanov J. Results of revascularization in patients with severe left ventricular dysfunction. ***J Thorac Cardiovasc Surg*** 2000; 119: 550-557.
5. Passamani E, Davis KB, Gillespie MJ, Killip T. CASS Principal Investigators and their Associates. A randomized trial of coronary artery bypass surgery. Survival of patients with a low ejection fraction. ***N Engl J Med*** 1985; 312: 1665-1671.
6. Salati M, Lemma M, Di Mattia DG, Danna P, Cialfi A, Salvaggia A, Santoli G. Myocardial revascularization in patients with ischemic cardiomyopathy: functional observations. ***Ann Thorac Surg*** 1997; 64: 1728-1734.
7. Trachiotis GD, Weintraub WS, Johnston TS, Jones EL, Guyton RA, Craver JM. Coronary artery bypass grafting in patients with advanced left ventricular dysfunction. ***Ann Thorac Surg*** 1998; 66: 1632-1639.
8. Kaul TK, Agnihotri AK, Fields BL, Riggins LS, Wyatt DA, Jones JR. Coronary artery bypass grafting in patients with an ejection fraction of twenty percent or less. ***J Thorac Cardiovasc Surg*** 1996; 111: 1001-1012.
9. Oliveira SF, Jatene AD, Solimena MC, de Oliveira SA, Meneguetti C, Jatene FB et al. Coronary Artery bypass graft surgery in patients with ischemic cardiomyopathy and severe left ventricular dysfunction: short and long-term results. Available from URL: http\\www.hsforum.com/vol2/issue1/1999-00625article.ht
10. Rahimtoola SH. The hibernating myocardium. ***Am Heart J*** 1989; 117: 211-221.
11. Kiat H, Maddahi J, Roy LH. Comparison of Tc-99m-methoxy-isobutryl-isonitrile with thallium imaging by planar and SPECT techniques for assessment of coronary artery disease. ***Am Heart J*** 1989; 117: 1-11.
12. Lucignani G, Paolini G, Landoni C, Zuccari M, Paganelli G, Galli L et al. Presurgical identification of hibernating myocardium by combined use of technetium-99m hexokinase 2-methoxyisobutlisonitrile single photon emission tomography and fluorine-18-fluoro-2-deoxy-D-glucose positron emission tomography in patients with coronary artery disease. ***Eur J Nucl Med*** 1992; 19: 874-881.
13. Bonow RO, Dilsizian V, Cuocolo A, Bacharah SL. Identification of viable myocardium in patients with coronary artery disease and left ventricular dysfunction. Comparison of thallium scintigraphy with reinjection and PET imaging with 18F-fluorodeoxyglucose. ***Circulation*** 1991; 83: 26-37.
14. Wechsler AS, Junod FI. Coronary bypass grafting in patients with chronic congestive heart failure. ***Circulation*** 1989; 79: 92-96.
15. Cerqueira MD, Harp GD, Ritchie JL. Quantitative gated blood tomographic assessment of regional ejection fraction:definition of normal limits. ***J Am Coll Cardiol*** 1993; 20: 934-941.
16. Louie HW, Laks H, Milgarter E, Drinkwater DC Jr, Hamilton MA, Brunken RC et al. Ischemic cardiomyopathy. Criteria for coronary revascularization and cardiac transplantation. ***Circulation*** 1991; 84: 290-295.
17. Bounous EP, Mark DB, Pollock BG, Hlatky MA, Harrell FE Jr, Lee KL et al. Surgical survival benefits for coronary disease patients with left ventricular dysfunction. ***Circulation*** 1988; 78: 151-157.
18. Alderman EL, Fisher LD, Litwin P, Kaiser GC, Myers NO, Maynard C et al. Results of coronary artery surgery in patients with poor left ventricular function (CASS). ***Circulation*** 1983; 68: 785-795.
19. Paolini G, Lucignani G, Zuccari M, Landoni C, Vanoli G, Di Credico G et al. Identification and revascularization of hibernating myocardium in angina free patients with left ventricular dysfunction. ***Eur J Cardio-thoracic Surg*** 1994; 8: 139-144.
20. Di Carli M, Davidson M, Little R, Khanna S, Mody FV, Brunken RC et al. Value of metabolic imaging with positron emission tomography for evaluating prognosis in patients with coronary artery disease and left ventricular dysfunction. ***Am J Cardiol*** 1994; 73: 527-533.
21. Ragosta M, Beller GA, Watson DD, Kaul S, Gimple LW. Quantitative planar rest-redistribution Tl-201 imaging in detection of myocardial viability and prediction of improvement in left ventricular function after coronary bypass surgery in patients with severely depressed left ventricular function. ***Circulation*** 1993; 87: 1630-1641.
22. Guyton RA, Arcidi JM, Langford DA, Norris DC, Liberman HA, Hatcher CR. Emergency coronary bypass for cardiogenic shock. ***Circulation*** 1987; 76: V22-V27.
23. Blakeman BM, Pifarre R, Sullivan H, Constanzo-Mordin MR, Zucker MJ. High-risk heart surgery in the heart transplant candidate. ***J Heart Transplant*** 1990; 9: 468-472.