Association between preoperative cardiac left ventricular dysfunction and perioperative intra-aortic balloon pump in patients undergoing off-pump coronary artery bypass surgery

Go Kusumoto MD, Kenji Shigematsu MD, Kouhei Iwashita MD, Kenji Tominaga MD, Takaaki Totoki MD, Ken Yamaura MD

Department of Anesthesiology, Fukuoka University School of Medicine, 7-45-1 Nanakuma, Jonan-ku, Fukuoka 814-0130, Japan

Keywords: Intra-aortic balloon pump; Off-pump coronary artery bypass surgery; Preoperative cardiac function; LV diastolic function; LV diastolic dysfunction

ABSTRACT

Background: Prophylactic use of intra-aortic balloon pump (IABP) reduces hospital mortality in patients with left ventricular (LV) systolic dysfunction undergoing coronary artery bypass surgery (CABG); however, its association in patients with LV diastolic dysfunction is unclear. This retrospective study investigated the association between preoperative LV function and perioperative use of IABP in patients undergoing off-pump CABG (OPCAB) at university hospital.

Methods: 100 consecutive patients who underwent OPCAB between January 1, 2011 and August 31, 2014 were studied. Preoperative LV function was categorized into four groups based on LV systolic and diastolic function determined with preoperative transthoracic echocardiography. The use of IABP was reviewed from medical records. The Mann–Whitney test, chi square test, or Fisher's exact test were used.

Results: Patients were categorized into the following groups: normal LV function (n-43), isolated LV systolic dysfunction (n=13), isolated LV diastolic dysfunction (n=21), and combined LV systolic and diastolic dysfunction (n=14). Intraoperative IABP use was significantly more frequent in patients with isolated LV systolic dysfunction, isolated LV diastolic dysfunction, and combined LV systolic and diastolic dysfunction than in those with normal LV function ($p < 0.05$). Furthermore, IABP was used more frequently in patients who developed combined LV systolic and diastolic dysfunction postoperatively ($p < 0.05$).

Conclusions: Not only the presence of preoperative systolic dysfunction but also LV diastolic dysfunction in the presence of normal LV systolic function were associated with increased use of IABP during and after OPCAB.

Introduction

The prophylactic use of intra-aortic balloon pump (IABP) has been shown to reduce in-hospital mortality in patients with left ventricular (LV) systolic dysfunction undergoing coronary artery bypass surgery (CABG) by meta-analysis of randomized controlled trials.[18,22]

LV diastolic dysfunction was recently reported as an independent predictor of intensive care unit (ICU) stays as well as 30-day and 1-year major adverse cardiac events in patients with preserved LV systolic function undergoing elective off-pump coronary artery bypass (OPCAB), emphasizing the importance of evaluation of both systolic and diastolic LV function in these patients.[8,14]

The purpose of this study was to investigate the association of preoperative cardiac function including LV diastolic function with perioperative IABP use in patients undergoing OPCAB.

Materials and Methods

This retrospective study included 100 consecutive patients who underwent primary OPCAB performed by a single surgeon at University Hospital between January 1, 2011 and August 31, 2014. This study was approved by the institutional ethics committee/review board (IRB No.14-7-11).

Clinical data for all patients including demographic and laboratory data, medical history, medication use, perioperative management, and postoperative outcomes were collected retrospectively from the anesthetic and medical records. Information collected included preoperative heart failure (HF), prior myocardial infarction (MI), renal dysfunction (serum creatinine > 2 mg/dl), hemodialysis (HD), and atrial fibrillation (AF).

Transthoracic echocardiography was performed by an experienced sonographer in all patients. Standard parasternal and apical two-and four-chamber views were obtained. LV ejection fraction (LVEF) was calculated using the biplane Simpson's technique. Early trans-mitral inflow velocity (E), deceleration time, and late trans-mitral inflow velocity (A) were determined using pulsed-wave Doppler echocardiography in the apical four chamber view, and E/A ratio was acquired. Early diastolic mitral annular velocity (e') was determined by pulsed-wave tissue Doppler imaging at the septal side of mitral annulus, and E/e' ratio was acquired.

In this study, patients were categorized into four groups: normal LV function, isolated LV systolic dysfunction, isolated LV diastolic dysfunction, and combined LV systolic and diastolic dysfunction. LV systolic dysfunction was defined as LVEF < 50%.[5]

LV diastolic dysfunction was defined as E/e' > 15 or E/e' between 8 and 15 with brain natriuretic peptide (BNP) > 200 pg/ml and/or AF.[21] LVEF > 50% without accompanying diastolic dysfunction was defined as normal LV function. Isolated LV systolic dysfunction was defined as LV systolic dysfunction (LVEF < 50%) in the presence of normal LV diastolic function. Isolated LV diastolic dysfunction was defined as LV diastolic dysfunction in the presence of normal LV systolic function. Combined LV systolic and diastolic dysfunction was defined as systolic dysfunction with concomitant LV diastolic dysfunction.

General anesthesia was induced with propofol, fentanyl and/or continuous infusion of remifentanil, and rocuronium or vecuronium. Anesthesia was maintained with propofol or sevoflurane, fentanyl or continuous infusion of remifentanil with an additional bolus infusion of fentanyl, and rocuronium or vecuronium. In addition to standard monitoring, additional monitoring included direct arterial pressure via a radial artery catheter, central venous pressure, pulmonary artery pressure, and mixed venous oxygen saturation. After anesthesia induction, all patients received continuous intravenous infusion of nitroglycerine, diltiazem, and a phosphodiesterase III inhibitor. Ephedrine, phenylephrine, dopamine, dobutamine, and/or norepinephrine were used if necessary. Packed red cells were transfused based on the discretion of the anesthesiologist. A cell salvage device was used in all patients. Heparin was administered at a dose of 100 IU/kg to achieve a target activated clotting time of 200–300 s after the dissection of internal mammary artery, radial artery, and/or saphenous vein grafts. Activated clotting time assessments were repeated every 60 min, and heparin was added as required. After completion of all anastomoses, protamine was administered at 1 mg/100 IU heparin and was supplemented as required to restore the activated clotting time to preoperative levels.

The adaptation of IABP use was not defined in detail in the medical and anesthetic records; however, in general, IABP was used intraoperatively in patients with refractory hemodynamic instability during anastomosis and postoperatively in patients with low cardiac output syndrome, at the discretion of the surgeon.

Patient characteristics, preoperative LV function, use of IABP, surgical and anesthetic data, length of ICU stay, intubation time, short-term adverse events, and mortality after OPCAB were extracted from the medical records.

Data were expressed as means ± SD. The Mann–Whitney test, chi square test, or Fisher's exact test were used for statistical analyses. Two-sided p values of less than 0.05 were considered as statistically significant.

Results

A total of 100 patients underwent OPCAB during the study period. After excluding patients with incomplete echocardiographic variables (n=9), data from 91 patients were included in the final analysis (Figure 1).

There were 43, 13, 21, and 14 patients in the normal LV function, isolated LV systolic dysfunction, isolated LV diastolic dysfunction, and combined LV systolic and diastolic dysfunction groups, respectively (Table 1). LV end-systolic and end-diastolic diameters were greater in patients with isolated LV systolic dysfunction and in those with combined LV systolic and diastolic dysfunction than in patients with normal LV function and in those with isolated LV systolic dysfunction ($p < 0.05$, Table 1).

Patient baseline characteristics according to LV function is shown in Table 2. Patients with combined LV systolic and diastolic dysfunction had higher European system for cardiac operative risk evaluation values (EuroSCORE) than those with normal LV function and isolated LV diastolic dysfunction ($p < 0.05$). The frequency of females was higher among patients with isolated LV diastolic dysfunction than those with normal LV function, isolated LV systolic dysfunction, and combined LV systolic and diastolic dysfunction ($p < 0.05$). Additionally, BNP levels were higher in patients with isolated LV systolic dysfunction, isolated LV diastolic dysfunction, and combined LV systolic and diastolic dysfunction than in those with normal LV function ($p < 0.05$). Patients with isolated LV systolic dysfunction had higher incidence of prior MI compared with patients with normal LV function ($p < 0.05$). Patients with isolated LV diastolic dysfunction had higher incidence of AF compared with patients with normal LV function and isolated LV systolic dysfunction ($p < 0.05$). Patients with combined LV systolic and diastolic dysfunction had higher incidence of hemodialysis compared with patients with normal LV function, and isolated LV diastolic dysfunction ($p < 0.05$).

Intraoperative use of IABP was more frequent in patients with isolated LV systolic dysfunction, isolated LV diastolic dysfunction, and combined LV systolic and diastolic dysfunction than patients with normal LV function ($p < 0.05$, Table 3).

Post-operative summary was shown in Table 4. Postoperative use of IABP was more frequent in patients with combined LV systolic and diastolic dysfunction than in those with normal LV function ($p < 0.05$).The length of ICU stay was longer and higher in patients with combined LV systolic and diastolic dysfunction than in those with isolated LV systolic dysfunction ($p < 0.05$). Moreover, newly developed bilateral plural effusion was more frequent in patients with combined LV systolic and diastolic dysfunction than in those with normal function and isolated LV diastolic dysfunction ($p < 0.05$).

Discussion

Our results indicated that not only LV systolic dysfunction but LV diastolic dysfunction in the presence of normal LV systolic function was associated with perioperative use of IABP.

Intraoperative IABP is recommended for acute HF in OPCAB,[4] especially during posterior vessel anastomoses in high risk patients with left main coronary artery stenosis, recent acute MI, unstable angina, or LVEF < 35%.[13] LV systolic dysfunction evaluated by EF is predicted to be a major risk factor for cardiac mortality in patients with heart disease. Long-term outcomes of OPCAB are closely related with cardiac function, and LV systolic function is suggested to be a major prognostic marker for adverse events associated with OPCAB.[1] The relationship of IABP use with LV systolic dysfunction is also reported,[1,25] but diastolic dysfunction is not well discussed and unclear because there are no established parameters of diastolic dysfunction.

The gold standard for diagnosis of LV diastolic dysfunction is measurement of elevated LV filling pressure by pressure monitoring; however, this approach cannot be routinely used. Therefore, several indices assessed by echocardiography, such as peak early-to-late trans-mitral flow velocity ratio (E/A), deceleration time (DcT), and systolic-to-diastolic pulmonary venous flow velocity ratio (S/D) with conventional Doppler, are traditionally used. However, these parameters are greatly influenced by loading conditions, heart rate, and rhythm disturbances and provide limited information in several clinical situations.[15,17,19] Recently introduced E/e' assessed by tissue Doppler was shown to be a good approximation of LV filling pressure even in patients with preserved or reduced LVEF, mitral regurgitation, or LV hypertrophy.[3,11] E/e' over 15 or between 8 and 15 and BNP > 200 pg/ml are considered to be consistent with the presence of increased LV filling pressure.[21] In this way, indices of diastolic dysfunction have become stable and independent. Consequently, assessment of LV diastolic function and the perioperative cardiac events have also become a focus of attention again. LV diastolic dysfunction has been shown to be associated with higher rates of morbidity and mortality during cardiac and non-cardiac surgeries.[2,3,6,7,9,12,14,16,24]

Our results indicated that not only isolated LV systolic dysfunction but isolated LV diastolic dysfunction with preserved LV systolic function were associated with perioperative use of IABP. The present study showed that even if the contractility is preserved, caution is necessary when the diastolic function is impaired. The reason why IABP usage increases in the case of diastolic dysfunction with preserved systolic function is not clear. However, in the case of diastolic dysfunction, the range of acceptance of LV diastolic volume is known as a narrow, and it is known that easily becomes hemodynamic instability, hypotension, pulmonary edema or HF. HF with preserved EF and concomitant diastolic dysfunction (HFpEF) accounts for approximately more than 50% of all patients with HF, and survival ratio associated with HFpEF is slightly higher than that with HF with reduced EF.[20] In non-cardiac surgical patients, the presence of perioperative diastolic dysfunction is an independent predictor of postoperative congestive HF, including pulmonary edema and prolonged length of hospital stay.[2,6,9,16] In the present study, all patients with preoperative heart failure had diastolic dysfunction and patients with isolated systolic dysfunction did not have heart failure.

Our results suggest that preoperative evaluation of not only the LV systolic but also the LV diastolic function is important in surgical patients. Our results also showed that combined LV systolic and diastolic dysfunction is higher risk than isolated LV systolic dysfunction. These results also showed that the combined use of systolic function by LVEF and diastolic function by E/e' was shown to be useful in predicting prognosis in patients with heart disease.[10]

In the present study, our results contradict recent reports showing a relationship between diastolic dysfunction and CABG prognosis. Preoperative control of our study population, which was based on the New York Heart Association (NYHA) functional classification, was relatively good, although EuroSCORE in patients with combined LV systolic and diastolic dysfunction was higher than that in patients with normal LV function and isolated LV diastolic dysfunction. In the present study, intraoperative use of IABP was significantly more frequent among patients with LV diastolic dysfunction, which could contribute to improved mid-term postoperative outcomes.[23]

The present study has several limitations. First, this was a retrospective study and perioperative treatment strategies were not controlled. Second, CABG was performed by one surgeon, whereas preoperative echocardiographic examinations and anesthetic management were performed by several sonographers and anesthesiologists. Thus, inter-observer and inter-anesthesiologist variabilities in data cannot be excluded. Third, the exact criteria for timing and use of IABP could not be identified, as they were determined for each patient by one surgeon.

In conclusion, not only isolated systolic dysfunction but the presence of preoperative LV diastolic dysfunction, isolated LV diastolic dysfunction, and combined LV systolic and diastolic dysfunction were associated with increased use of IABP during and after OPCAB.

Acknowledgments: The authors would like to thank Enago (www.enago.jp) for the English language review.

This research did not receive any specific grant from funding agencies in the public, commercial, or not-for-profit sectors.

REFERENCES

1. Arom KV, Emery RW, Flavin TF, Kshettry VR, Petersen RJ. 2001. OPCAB surgery: a critical review of two different categories of pre-operative ejection fraction. Eur J Cardiothorac Surg 20:533-537.

2. Canet E, Osman D, Lambert J, et al. 2011. Acute respiratory failure in kidney transplant recipients: a multicenter study. Crit Care 15:R91. http://ccforum.biomedcentral.com/articles/10.1186/cc10091

3. Chang SA, Park PW, Sung K, et al. 2010. Noninvasive estimate of left ventricular filling pressure correlated with early and midterm postoperative cardiovascular events after isolated aortic valve replacement in patients with severe aortic stenosis. J Thorac Cardiovasc Surg 140:1361-1366. http://dx.doi.org/10.1016/j.jtcvs.2010.02.022

4. Chassot PG, van der Linden P, Zaugg M, Mueller XM, Spahn DR. 2004. Off-pump coronary artery bypass surgery: physiology and anaesthetic management. Br J Anaesth 92:400-413. https://doi.org/10.1093/bja/aeh064

5. Dickstein K, Cohen-Solal A, Filippatos G, et al. 2008. ESC guidelines for the diagnosis and treatment of acute and chronic heart failure 2008. Eur heart J 29:2388-2442. https://doi.org/10.1093/eurheartj/ehn309

6. Fayad A, Ansari MT, Yang H, Ruddy T, Wells GA. 2016. Perioperative diastolic dysfunction in patients undergoing noncardiac surgery is an independent risk factor for cardiovascular events. Anesthesiology 125:72-91. DOI: 10.1097/ALN.0000000000001132

7. Flu WJ, van Kuijk JP, Hoeks SE, et al. 2010. Prognostic implications of asymptomatic left ventricular dysfunction in patients undergoing vascular surgery. Anesthesiology 112:1316-1324. DOI: 10.1097/ALN.0b013e3181da89ca

8. Groban L, Sanders DM, Houle TT, et al. 2010. Prognostic value of tissue Doppler-derived E/e’ on early morbid events after cardiac surgery. Echocardiography 27:131-138. DOI: 10.1111/j.1540-8175.2009.01076.x

9. Higashi M, Yamaura K, Ikeda M, Shimauchi T, Saiki H, Hoka S. 2013. Diastolic dysfunction of the left ventricle is associated with pulmonary edema after renal transplantation. Acta Anaesthesiol Scand 57:1154-1160. doi: 10.1111/aas.12168.

10. Hirata K, Hyodo E, Hozumi T, et al. 2009. Usefulness of a combination of systolic function by left ventricular ejection fraction and diastolic function by E/E’ to predict prognosis in patients with heart failure. Am J Cardiol 103:1275-1279. http://dx.doi.org/10.1016/j.amjcard.2009.01.024

11. Iwabuchi Y, Ogawa T, Inoue T, Otsuka K, Nitta K. 2012. Elevated E/E' predicts cardiovascular events in hemodialysis patients with preserved systolic function. Intern Med 51:155-160. http://doi.org/10.2169/internalmedicine.51.6250

12. Kaw R, Hernandez AV, Pasupuleti V, et al. 2016. Effect of diastolic dysfunction on postoperative outcomes after cardiovascular surgery: A systematic review and meta-analysis. J Thorac Cardiovasc Surg, 152:1142-1153. http://dx.doi.org/10.1016/j.jtcvs.2016.05.057

13. Kim KB, Lim C, Ahn H, Yang JK. 2001. Intraaortic balloon pump therapy facilitates posterior vessel off-pump coronary artery bypass grafting in high-risk patients. Ann Thorac Surg 71:1964-1968. http://dx.doi.org/10.1016/S0003-4975(01)02638-8

14. Lee EH, Yun SC, Chin JH, et al. 2012. Prognostic implications of preoperative E/e' ratio in patients with off-pump coronary artery surgery. Anesthesiology 116:362-371.

15. Leite-Moreina AF. 2006. Current perspectives in diastolic dysfunction and diastolic heart failure. Heart 92:712-18. http://dx.doi.org/10.1136/hrt.2005.062950

16. Matyal R, Hess PE, Subramaniam B, et al. 2009. Perioperative diastolic dysfunction during vascular surgery and its association with postoperative outcome. J Vasc Surg 50:70-76. http://dx.doi.org/10.1016/j.jvs.2008.12.032

17. Matyal R, Skubas NJ, Shernan SK, Mahmood F. 2011. Perioperative assessment of diastolic dysfunction. Anesth Analg 113:449-472. DOI: 10.1213/ANE.0b013e31822649ac

18. Miceli A, Fiorani B, Danesi TH, Melina G, Sinatra R. 2009. Prophylactic intra-aortic balloon pump in high-risk patients undergoing coronary artery bypass grafting: a propensity score analysis. Interact Cardiovasc Thorac Surg 9:291-294. https://doi.org/10.1510/icvts.2008.196105

19. Nishimura RA, Tajik AJ. 1997. Evaluation of diastolic filling of left ventricle in health and disease: Doppler echocardiography is the clinician's Rosetta Stone. J Am Coll Cardiol 30:8-18. http://dx.doi.org/10.1016/S0735-1097(97)00144-7

20. Owan TE, Hodge DO, Herges RM, Jacobsen SJ, Roger VL, Redfield MM. 2006. Trends in prevalence and outcomes of heart failure with preserved ejection fraction. N Engl J Med 355:251-259. DOI: 10.1056/NEJMoa052256

21. Paulus WJ, Tschope C, Sanderson JE, et al. 2007. How to diagnose heart failure: a consensus statement on the diagnosis of heart failure with normal left ventricular ejection fraction by the Heart Failure and Echocardiography Associations of the European Society of Cardiology. Eur Heart J 28:2539-2550.

https://doi.org/10.1093/eurheartj/ehm037
22. Pompeu M, Ferraz PE, Escobar RR, et al. 2012. Prophylactic intra-aortic balloon pump in high-risk patients undergoing coronary artery bypass surgery: a meta-analysis of randomized controlled trials. Coron Artery Dis 23:480-486. DOI: 10.1097/MCA.0b013e3283358784d
23. Rubino AS, Onorati F, Santarpino G, et al.2009. Early intra-aortic balloon pumping following perioperative myocardial injury improves hospital and mid-term prognosis. Interact Cardiovasc Thorac Surg 8:310-315. https://doi.org/10.1510/icvts.2008.190884
24. Salem R, Denault AY, Couture P, et al. 2006. Left ventricular end-diastolic pressure is a predictor of mortality in cardiac surgery independently of left ventricular ejection fraction. Br J Anaesth 97:292-297. https://doi.org/10.1093/bja/ael140
25. Yang F, Wang J, Hou D, et al. 2016. Preoperative intra-aortic balloon pump improves the clinical outcomes of off-pump coronary artery bypass grafting in left ventricular dysfunction patients. Sci Rep 6:27645. doi: 10.1038/srep27645

Figure legends

Figure 1. Study inclusion/exclusion flow diagram.

A total of 100 patients underwent off-pump coronary artery bypass surgery during the study period. After excluding patients without echocardiographic parameters (n = 9), data from the remaining 91 patients were included in the final analysis.

Reprint address

Corresponding author: Ken Yamaura
Department of Anesthesiology, Fukuoka University School of Medicine
7-45-1 Nanakuma, Jonan-ku, Fukuoka 814-0130, Japan
Phone numbers: + 81-92-801-1011
Facsimile numbers: +81-92-801-1025
E-mail: keny@fukuoka-u.ac.jp

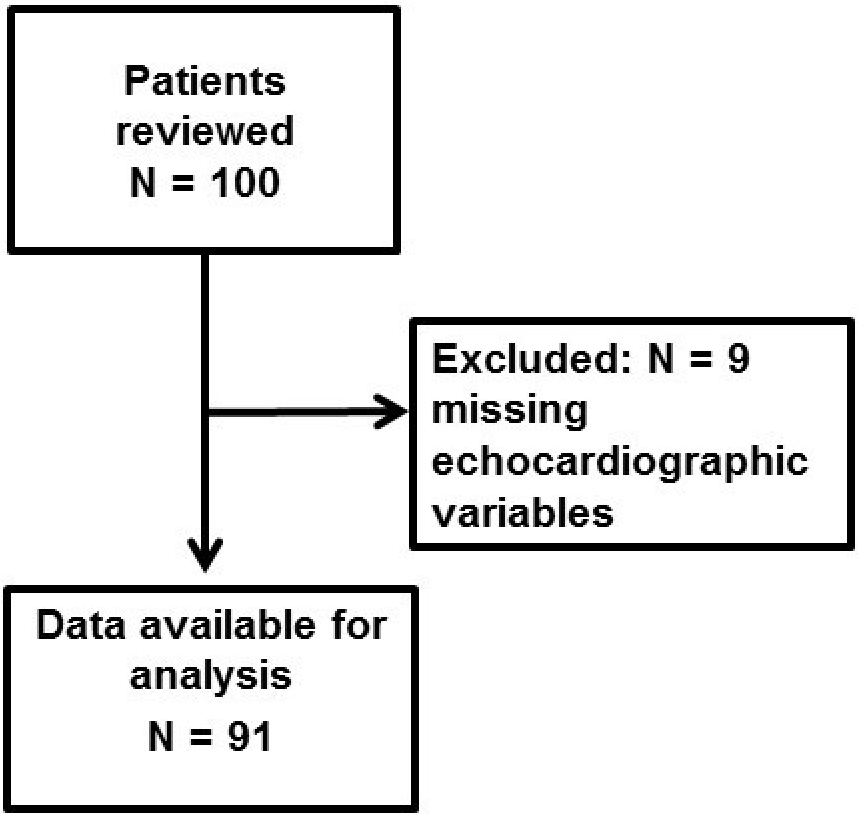
Patients
reviewed
N = 100
Excluded: N = 9
missing
echocardiographic
variables
Data available for
analysis
N = 91

Table 1. Preoperative transthoracic echocardiographic variables

Echocardiographic variables	Left ventricular function			
	Normal function (n = 43)	Isolated systolic dysfunction (n = 13)	Isolated diastolic dysfunction (n = 21)	Combined systolic and diastolic dysfunction (n = 14)
LVEF (%)	66.3 ± 6.7	39.6 ± 9.2*	67.6 ± 9.1†	34.6 ± 5.7*‡
LAD (mm)	38.2 ± 5.1	39.3 ± 6.3	39.2 ± 5.6	42.6 ± 7.2*
IVST (mm)	9.9 ± 1.5	9.0 ± 2.2	10.2 ± 1.7	9.8 ± 1.6
PWT (mm)	10.4 ± 1.6	9.4 ± 1.0*	10.0 ± 1.5	10.1 ± 1.5
LVDs (mm)	29.1 ± 4.9	42.9 ± 7.6*	28.7 ± 4.7†	44.7 ± 6.2*‡
LVDd (mm)	45.9 ± 5.3	53.8 ± 7.4*	46.0 ± 4.2†	53.7 ± 5.6*‡
E/A ratio	0.75 ± 0.16	0.77 ± 0.19	0.75 ± 0.23	0.82 ± 0.31
DcT (ms)	207.0 ± 65.1	225.2 ± 76.3	249.5 ± 61.1*	192.9 ± 65.4‡
E/E' ratio	8.7 ± 2.6	9.4 ± 2.7	16.7 ± 7.3*†	16.6 ± 5.1*†

Data are expressed as number of patients or mean ± standard deviation.

LVEF, left ventricular ejection fraction; LAD, left atrial diameter; IVS, interventricular septum thickness; PWT, posterior wall thickness; LVDs, left ventricular end diastolic diameter; LVDd, left ventricular end systolic diameter; E/A, ratio of peak early and late flow of mitral inflow; DcT, Deceleration time; E/E', ratio of LV early diastolic filling velocity to the peak diastolic velocity of mitral septal annulus.

* $p < 0.05$ compared with normal function; † $p < 0.05$ compared with isolated systolic dysfunction; ‡ $p < 0.05$ compared with isolated diastolic dysfunction

Table 2. Baseline characteristics of patients

	Left ventricular function			
	Normal function (n = 43)	Isolated systolic dysfunction (n = 13)	Isolated diastolic dysfunction (n = 21)	Combined systolic and diastolic dysfunction (n = 14)
Age (years)	67.3 ± 9.2	66.2 ± 8.2	71.5 ± 7.3	68.2 ± 12.2
Female (%)	14.0	7.7	52.4*†	7.1‡
BMI (kg/m^2)	24.7 ± 4.6	22.7 ± 2.5	23.4 ± 3.9	23.2 ± 4.1
EuroSCORE	2.0 ± 1.3	2.7 ± 1.6	2.7 ± 1.7	4.0 ± 1.8*‡
NYHA (I/II/III/IV)	34/9/0/0	10/3/0/0	15/3/2/1	9/2/3/0
BNP (pg/ml)	35.6 ± 37.9	93.4 ± 55.5*	96.2 ± 107.6*	636.2 ± 539.1*†‡
Heart failure	0	0	3*	2
prior MI	9	11*	4†	5†
Hypertension	39	13	20	14
Diabetes mellitus	30	5	12	10
Hypercholesterolemia	37	9	20	7*‡
Atrial fibrillation	1	0	7*†	0‡
COPD	2	2	1	2
Renal dysfunction	4	1	3	6*
Hemodialysis	2	1	1	6*‡

Data are expressed as number of patients or mean ± standard deviation.

BMI, body mass index; EuroSCORE, European system for cardiac operative risk evaluation; NYHA, New York Heart Association functional classification; BNP, brain natriuretic peptide; MI, myocardial infarction; COPD, chronic obstructive pulmonary disease.

* $p < 0.05$ compared with normal function; † $p < 0.05$ compared with isolated systolic dysfunction; ‡ $p < 0.05$ compared with isolated diastolic dysfunction

Table 3. Intra-operative summary

IABP; intra-aortic balloon pump

	Left ventricular function			
	Normal function (n = 43)	Isolated systolic dysfunction (n = 13)	Isolated diastolic dysfunction (n = 21)	Combined systolic and diastolic dysfunction (n = 14)
Anesthesia time (min)	468.7 ± 59.5	481.9 ± 59.9	449.5 ± 67.5	466.1 ± 100.9
Operation time (min)	344.0 ± 53.6	362.1 ± 53.6	343.2 ± 64.4	348.2 ± 93.0
Grafts anastomosis (n)	4.4 ± 1.0	3.8 ± 0.7*	4.0 ± 1.1	4.2 ± 1.2
IABP (n)	1	3*	6*	6*

* $p < 0.05$ compared with normal function.

Table 4. Post-operative summary

	Left ventricular function			
	Normal function (n = 43)	Isolated systolic dysfunction (n = 13)	Isolated diastolic dysfunction (n = 21)	Combined systolic and diastolic dysfunction (n = 14)
Intubation time (h)	16.1 ± 15.9	12.3 ± 17.9*	19.3 ± 24.4	61.6 ± 173.5
ICU stay (h)	109.7 ± 85.2	88.5 ± 71.3	107.0 ± 73.2	157.9 ± 161.4†
Death (n)	0	0	0	0
IABP (n)	2	1	3	4*
Duration of inotropic support (h)	67.1 ± 48.0	59.3 ± 40.1	73.0 ± 48.3	101.6 ± 90.0
New MI	0	0	1	0
Pleural effusion(n)	3	1	0	5*‡
New AF (n)	9	2	2	4
cerebral infarction (n)	0	0	1	0
New AKI (n)	13	2	2	4
RRT (n)	0	0	0	1

Data are expressed as means ± standard deviation or number of patients.

ICU, intensive care unit; IABP; intra-aortic balloon pump; MI, newly developed myocardial infarction; Plural effusion, newly developed bilateral plural effusion; New AF, newly developed atrial fibrillation; New AKI, newly developed acute kidney injury; RRT, newly developed renal replacement therapy.

* $p < 0.05$ compared with normal function; † $p < 0.05$ compared with isolated systolic dysfunction; ‡ $p < 0.05$ compared with isolated diastolic dysfunction