Left Ventricular Size and Outcomes in Patients With Left Ventricular Ejection Fraction Less Than 20%

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Background. **The interactive relationship between left ventricular (LV) ejection fraction (LVEF) and LV size in predicting perioperative outcomes after cardiac surgery has not been clarified.**

Methods. **This study reviewed all patients who underwent cardiac surgery between 2010 and 2016 with either preserved LVEF (>60%; n = 5685) or severely reduced LVEF (<20%; n = 143). LV size was categorized by using either LV end-diastolic or end-systolic diameter or a qualitative assessment, as follows: normal, smaller than 4 cm; mildly enlarged, 4.1 to 5.4 cm moderately enlarged, 5.5 to 6.5 cm; and severely enlarged, larger than 6.5 cm. Using propensity-score analysis, we matched patients with LVEF less than 20% (n = 143) in a 3:1 ratio with patients with LVEF greater than 60% (n = 429).**

Results. **There were significant differences in mortality, major morbidity, and operative mortality and prolonged length of stay between patients with LVEF less than 20% and LVEF greater than 60%. In patients with LVEF less than 20%, there were no significant differences in outcomes between those with an LV size of 5.4 cm or smaller and an LV size of 5.5 cm or larger. In patients undergoing isolated coronary artery bypass grafting (CABG), LV size predicted mortality, major morbidity, and operative mortality (odds ratio, 5.5 [95% confidence interval, 2.0 to 15.7]; *P* < .001) and prolonged length of stay (odds ratio, 3.4 [95% confidence interval, 1.2 to 10.3]; *P* = .026), respectively.**

Conclusions. **LVEF is more important than LV size in predicting outcomes after cardiac surgery. However, in patients undergoing isolated CABG, LV size has an interactive effect with LVEF and can potentially aid the decision-making process. Risk adjustment models using only LVEF may be inaccurate, particularly with respect to isolated CABG procedures.**

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Severe left ventricular (LV) dysfunction is associated with increased risk of short- and long-term mortality after coronary artery bypass grafting (CABG) and valvular surgery,[1-5] and this increased risk is higher than 10% in some studies.[1,4-7] Outcomes after cardiac surgery for patients with severe LV dysfunction have improved dramatically[2,3,5,8,9] as a result of advances in surgical techniques, perioperative myocardial protection, and postoperative pharmacologic and mechanical support.[5] Additionally, the Surgical Treatment for Ischemic Heart Failure (STICH) trial demonstrated that compared with medical therapy, patients with severe LV dysfunction who underwent isolated CABG had lower rates of all-cause and cardiovascular mortality and lower rates of hospitalization for cardiovascular causes.[9]

Our group has previously reported acceptable midterm outcomes after conventional open heart surgery in patients who met criteria for advanced therapies, thus demonstrating that this could be an alternative to advanced treatments for highly selected patients with severe LV dysfunction.[10]

These previously reported outcomes, however, were based solely on LV ejection fraction (LVEF) and did not take into consideration other patient characteristics such as LV size.

Yamaguchi and colleagues[11] suggested that a preoperative LV end-systolic volume index greater than 100 mL/m^2 predicted the development of postoperative congestive heart failure and reduced survival rates in patients with ischemic cardiomyopathy and severe LV dysfunction.

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Moreover, this index was predictive of LV function.[12] These data suggest that LV volume or size can be a useful parameter to decide whether patients should undergo cardiac surgery or be referred for advanced therapies.

To date, the interactive relationship between LV size and LVEF in predicting perioperative outcomes after cardiac surgery has not been clarified. This study aimed to compare postoperative outcomes after cardiac surgery among patients with preserved LVEF, patients with severe LV dysfunction and normal to mild LV enlargement, and those with severe LV dysfunction and moderate to severe LV enlargement. Furthermore, we aimed to study the impact of LV size on postoperative outcomes stratified by type of procedure.

Patients and Methods

This study was reviewed and approved by our institutional Research Ethics Board of the University Health Network. Individual patient consent was waived because this was a retrospective analysis of de-identified data collected prospectively in our institutional database.

Patient Population

Patients who underwent cardiac surgery at the Peter Munk Cardiac Centre, University Health Network between 2010 and 2016 and who had either normal (LVEF >60%) (n = 5685) or severely reduced (LVEF <20%) LVEF (n = 143) were included. Patients who underwent heart transplantation, had a planned ventricular assist device implanted, or had mild to moderate LV dysfunction (LVEF between 20% and 59%) were excluded.

Patients with severe LV dysfunction were further subdivided according to LV end-diastolic diameter, LV end-systolic diameter, or a qualitative assessment, in that order, depending on which measurement or assessment was available. Of the total 143 study participants with an LVEF less than 20%, 126 (88%) had either a quantitative or qualitative assessment of LV size available. Of those patients, 108 (86%) were classified on the basis of LV end-diastolic diameter, and 18 (14%) were classified according to the qualitative assessment. Quantitative assessments were derived from echocardiogram-based measurements. LV size was classified as follows: normal, smaller than 4 cm, mildly enlarged, 4.1 to 5.4 cm; moderately enlarged, 5.5 to 6.5 cm; and severely enlarged, larger than 6.5 cm. Patients in the preserved LVEF group were assumed to have normal LV size.

Outcomes

The primary end points were as follows: all-cause mortality; major morbidity or operative mortality, which included operative mortality; prolonged ventilation; reoperation; permanent stroke; postoperative renal failure; postoperative deep sternal infection; and prolonged length of stay (≥14 days from the date of surgery). The secondary end points of interest were the total length of stay and the duration of mechanical ventilation.

Statistical Analysis

Baseline characteristics were summarized using descriptive statistics. Continuous variables were summarized using mean ± SD or median (interquartile range) as appropriate. Dichotomous and polytomous variables were summarized in terms of frequencies and proportions.

Logistic regression was used to derive a propensity score for belonging to the LVEF less than 20% group vs the LVEF greater than 60% group. Automated variable selection was used to generate the propensity score. The variables selected in the regression model were age, sex, year of surgery, the Society of Thoracic Surgeons (STS) category of surgery (isolated CABG, isolated valve procedure, combined CABG and valve procedure, other), preoperative dyslipidemia, preoperative hypertension, and previous cardiac intervention.

Propensity-score matching was performed using a greedy algorithm without replacement with a maximum allowable difference in propensity score within pairs of 0.03.

Participants in the LVEF less than 20% group were matched in a 1:3 ratio with participants in the LVEF greater than 60% group by using the previously calculated propensity score (see detailed description in Supplemental Table 1). This showed that there was still an imbalance of surgery types (according to STS surgical categories). For this reason, we also performed a match that was based on propensity score with a maximal allowable distance of 0.03 with the additional criteria of an exact match on STS surgical category.

Generalized linear models were used to determine whether there were significant differences in the proportion of perioperative outcomes across the following groups: preserved LVEF (LVEF >60%), severe LV dysfunction with normal to mildly enlarged LV size (LVEF <20%/LV size ≤5.4 cm), and severe LV dysfunction with moderate to severely enlarged LV size (LVEF <20%/LV size ≥5.5 cm). Propensity matching and statistical analyses were performed using SAS software version 9.4 (SAS, Cary, NC).

Results

The baseline characteristics of the overall cohort before matching are demonstrated in Table 1. Supplemental Figure 1 shows the distribution of propensity scores for all eligible participants.

The demographic and preoperative characteristics of the matched cohort are summarized in Table 2. This is the group that was used in further analyses.

Median age was 64 years (interquartile range, 56 to 71 years), and more than 80% of patients were male. Regarding STS surgical category, the majority of patients underwent isolated CABG (39% in both groups). More than 10% of patients had a history of previous cardiac intervention. Preoperative viability assessments were performed in 66 patients (46.1%) with an LVEF of less than 20% (Table 2). Among them, 65 patients had viability in some myocardial territories. One did not show viability in any territories and underwent CABG in combination with mitral valve

Table 1. Demographic Characteristics of the Entire Cohort

Variable	LVEF >60% (n = 5685)	LVEF <20% (n = 143)	*P* Value
Age, y	65 (55-73)	64 (56-71)	.21
Sex, male	3795 (66.8)	118 (82.5)	<.001
Year of surgery			.15
2010	944 (16.6)	28 (19.6)	
2011	886 (15.6)	28 (19.6)	
2012	928 (16.3)	20 (14.0)	
2013	917 (16.1)	30 (21.0)	
2014	798 (14.0)	17 (11.9)	
2015	554 (9.7)	7 (4.9)	
2016	658 (11.6)	13 (9.1)	
STS category			.001
Isolated CABG	2129 (37.4)	55 (38.5)	
Isolated valve procedure	811 (14.3)	8 (5.6)	
CABG and valve combined	433 (7.6)	20 (14.0)	
Other	2312 (40.7)	60 (42.0)	
Preoperative hypertension	3741 (65.8)	90 (62.9)	.48
Preoperative dyslipidemia	3488 (61.4)	93 (65.0)	.39
Previous cardiac intervention	673 (11.8)	21 (14.7)	.30

Continuous variables are presented as median (interquartile range); categorical variables are summarized as n (%).

CABG, coronary artery bypass grafting; LVEF, left ventricular ejection fraction; STS The Society of Thoracic Surgeons.

replacement. Postoperative short-term intraaortic balloon pumping was required.

Left Ventricular Dysfunction Affects Postoperative Outcomes

We initially compared postoperative outcomes for all surgical interventions combined. As seen in Table 3, overall mortality rates were significantly higher in the LVEF less than 20% group compared with patients with preserved LVEF ($P < .001$). Similarly, major morbidity and operative mortality and prolonged length of stay were significantly greater in the LVEF less than 20% group compared with patients with preserved LVEF ($P < .001$). A total of 19 patients (13.3%) with LVEF less than 20% required short-term postoperative intraaortic balloon pumping, and 2 (1.4%) required a biventricular assist device.

Using generalized linear models to determine whether there were significant differences in the proportion of perioperative outcomes across the groups, we confirmed the significant differences seen between the groups with LVEF less than 20% and LVEF greater than 60% (Table 4). However, in all patients with LVEF less than20%, no significant differences were observed between the subgroups of patients with an LV size of 5.4 cm or smaller and an LV size of 5.5 cm or larger.

Patients with severe LV dysfunction had a significantly greater median length of stay and duration of mechanical ventilation compared with patients with preserved LVEF ($P < .001$) (Supplemental Table 2). However, in patients with an LVEF of less than 20%, there was no significant difference in either length of stay or ventilation duration between the subgroups with an LV size of 5.4 cm or smaller and an LV size of 5.5 cm or larger ($P = .66$ for length of stay and $P = .97$ for ventilation duration).

An ischemic cause was present in 68 patients; 13 patients (9.1%) had ischemic mitral regurgitation, and all underwent CABG (average bypass grafts, 3.5 ± 0.7) in combination with mitral valve surgery (repair, 8; replacement, 5). The median age was 64 years (range, 44 to 79 years), and 11 patients were male. Two patients had an LV size of 5.4 cm or smaller, and 11 had an LV size of 5.5 cm or larger preoperatively. One patient in each group died of multiorgan failure and intraoperative bleeding. Both received biologic mitral valve replacements. Two patients with an LV size of 5.5 cm or larger required short-term postoperative intraaortic balloon pump support. Eventually, both patients recovered and were discharged home without any complications.

Table 2. Demographic Characteristics After Matching on Propensity Score and STS Procedure Category

Variable	LVEF >60% (n = 429)	LVEF <20% (n = 143)	*P* Value
Age, y	64 (56-71)	64 (56-71)	.52
Sex, male	349 (81.4)	118 (82.5)	.80
Year of surgery			.88
2010	83 (19.3)	28 (19.6)	
2011	96 (22.4)	28 (19.6)	
2012	63 (14.7)	20 (14.0)	
2013	83 (19.3)	30 (21.0)	
2014	59 (13.8)	17 (11.9)	
2015	19 (4.4)	7 (4.9)	
2016	26 (6.1)	13 (9.1)	
STS category			1.0
Isolated CABG	165 (38.5)	55 (38.5)	
Isolated valve procedure	24 (5.6)	8 (5.6)	
CABG and valve procedure combined	60 (14.0)	20 (14.0)	
Other	180 (42.0)	60 (42.0)	
Preoperative hypertension	299 (69.7)	90 (62.9)	.15
Preoperative dyslipidemia	309 (72.0)	93 (65.0)	.11
Previous cardiac intervention	45 (10.5)	21 (14.7)	.18
Viability assessment			
MRI	…	33 (23.1)	…
SPECT	…	26 (18.2)	…
PET	…	7 (4.9)	…
Stress echocardiography	…	6 (4.2)	…

Continuous variables are presented as median (interquartile range); categorical variables are summarized as n (%).

CABG, coronary artery bypass grafting; LVEF, left ventricular ejection fraction; MRI, magnetic resonance imaging; PET, positron emission tomography; SPECT, single photon emission computed tomography; STS, The Society of Thoracic Surgeons.

Left Ventricular Enlargement Affects Postoperative Outcomes in Isolated Coronary Artery Bypass Grafting

We performed an analysis in the subgroup of patients undergoing isolated CABG. We identified patients who

Table 3. Perioperative Outcomes in Each Group

Outcomes	LVEF >60% (n = 429)	LVEF <20%		*P* Value
		LV Size ≥5.5 cm (n = 90)	LV Size ≤5.4 cm (n = 36)	
Mortality	8 (1.9)	10 (11.1)	6 (16.7)	<.001
Major morbidity and operative mortality	43 (10.0)	29 (32.2)	10 (27.8)	<.001
Prolonged length of stay	37 (8.6)	27 (30.3)	7 (25.0)	<.001

Categorical variables are summarized as n (%).

LVEF, left ventricular ejection fraction.

underwent isolated CABG with LVEF greater than 60% (n = 165) and LVEF less than 20% (n = 44) (Table 5). As seen in Figure 1, overall mortality and major morbidity and operative mortality rates were significantly higher in the LVEF less than 20% group compared with patients with preserved LVEF. We were not able to detect a significant difference in the rates of prolonged length of stay (*P* = .05).

As described earlier, generalized linear models were applied to determine whether there were significant differences in the proportion of perioperative outcomes across the groups (Figure 2).

The group with LVEF less than 20% and LV size of 5.5 cm or greater demonstrated a significantly greater mortality when compared with the LVEF greater than 60% group (*P* = .007). When patients with an LVEF less than 20% and an LV size of 5.4 cm or smaller were compared with patients with preserved LVEF, however, a nonsignificant difference was found (*P* = .098).

Table 4. Relative Risk (Odds Ratios and 95% Confidence Intervals) for Comparisons Across Groups

Comparison	OR [95% CI]	*P* Value
Mortality		
LVEF <20%/LV size ≥5.5 cm vs LVEF >60%	6.6 [2.5-17.2]	<.001
LVEF <20%/LV size ≤5.4 cm vs LVEF >60%	10.5 [3.4-32.3]	<.001
LVEF <20%/LV size ≤5.4 cm vs LVEF <20%/LV size ≥5.5cm	1.6 [0.5-4.8]	.40
Major morbidity and operative mortality		
LVEF <20% /LV size ≥5.5 cm vs LVEF >60%	4.3 [2.5-7.3]	<.001
LVEF <20%/LV size ≤5.4 cm vs LVEF >60%	3.5 [1.6-7.6]	.002
LVEF <20%/LV size ≤5.4 cm vs LVEF <20%/LV size ≥5.5 cm	0.8 [0.3-1.9]	.63
Prolonged length of stay (≥14 days)		
LVEF <20%/LV size ≥5.5 cm vs LVEF >60%	4.6 [2.6-8.1]	<.001
LVEF <20%/LV size ≤5.4 cm vs LVEF >60%	3.5 [1.5-8.0]	.003
LVEF <20%/LV size ≤5.4 cm vs LVEF <20%/LV size ≥5.5 cm	0.8 [0.3-1.8]	.55

CI, confidence interval; LV, left ventricular; LVEF, left ventricular ejection fraction; OR, odds ratio.

The odds ratio for LVEF less than 20% with LV size of 5.4 cm or smaller to LVEF greater than 60% in major morbidity and operative mortality and prolonged length of stay was 3.9 (95% confidence interval [CI], 0.7 to 20.5; *P* = .11) and 1.6 (95% CI, 0.2 to 13.3; *P* = .69), respectively.

Furthermore, there was a significant difference in median length of stay and ventilation duration between the groups (*P* < .001) (Supplemental Table 3). However, there was no significant difference in either length of stay or ventilation duration specifically between the groups with an LV size of 5.4 cm or smaller and an LV size of 5.5 cm or greater (*P* = .18 for length of stay and *P* = .57 for ventilation duration).

Comment

In the present study, we demonstrated that patients with LVEF less than 20% have higher rates of mortality, major morbidity and operative mortality, and prolonged length

Table 5. Demographic Characteristics for Isolated Coronary Artery Bypass Grafting Subgroup After Propensity-Score Matching

Variable	LVEF >60% (n = 165)	LVEF <20%		*P* Value
		≥5.5 cm (n = 33)	≤5.4 cm (n = 11)	
Age, y	66 (60-71)	67 (59-74)	63 (58-70)	.54
Sex, male	147 (89.1)	31 (93.9)	8 (72.7)	.14
Year of surgery				.64
2010	25 (15.2)	3 (9.1)	28 (19.6)	
2011	35 (22.1)	5 (15.2)	28 (19.6)	
2012	21 (12.7)	8 (24.2)	20 (14.0)	
2013	41 (24.8)	7 (21.2)	30 (21.0)	
2014	31 (13.8)	5 (15.2)	17 (11.9)	
2015	9 (5.5)	3 (9.1)	7 (4.9)	
2016	3 (1.8)	2 (6.1)	13 (9.1)	
Preoperative hypertension	140 (84.8)	22 (66.7)	9 (81.8)	.04
Preoperative dyslipidemia	150 (90.9)	23 (69.7)	9 (81.8)	.004
Previous cardiac intervention	7 (4.2%)	3 (9.1)	0 (0.0)	.43

Continuous variables are presented as median (interquartile range); categorical variables are summarized as n (%).

LVEF, left ventricular ejection fraction; STS The Society of Thoracic Surgeons.

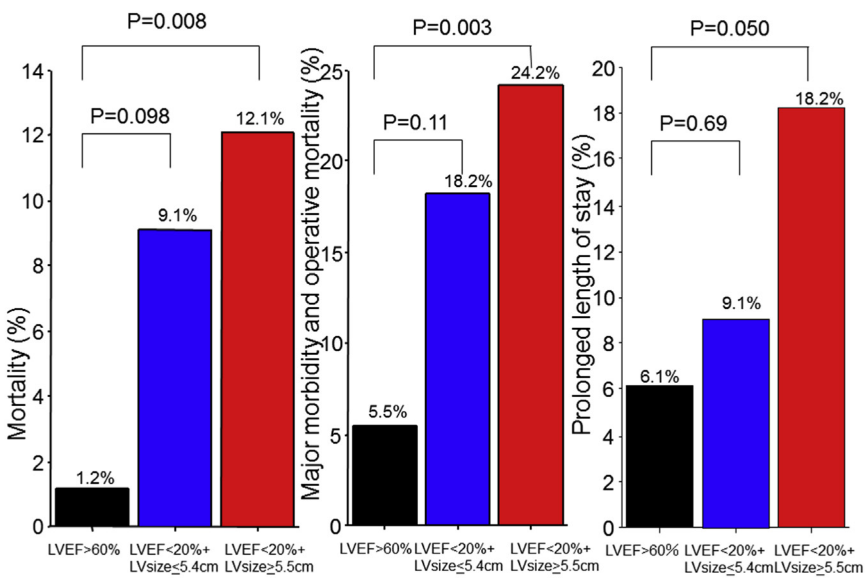

Figure 1. Postoperative outcomes in patients undergoing isolated coronary artery bypass grafting. There is an interactive effect of both left ventricular (LV) size and function on mortality, morbidity, and length of stay after surgery. (LVEF, left ventricular ejection fraction.)

of stay after cardiac surgery irrespective of preoperative LV size compared with rates in patients with preserved LVEF. Although this is not a novel finding, we further stratified our analysis on the basis of LV size. In participants with isolated CABG, there were no significant differences in perioperative outcomes between patients with LVEF less than 20% and LV size of 5.4 cm and smaller and patients with preserved LVEF. Therefore, even patients with extreme LV dysfunction are not at significantly increased operative risk provided LV dilatation has not yet developed. In contrast, morbidity and mortality were significantly higher in those patients with LV dysfunction and LV enlargement.

According to previous publications, the mortality rate in patients with LVEF less than 20% who were undergoing CABG or valve surgery was high, approaching 17%.[2,5,13,14] However, most studies describing outcomes in high-risk patients have applied LVEF as an inclusion criterion, and patient populations were not well defined. In addition, it is quite difficult to differentiate between dysfunctional myocardium secondary to reversible ischemia or hibernating myocardium and dysfunctional myocardium secondary to fibrosis from a previous infarction by using only LVEF.[15] There was also no relationship between preoperative LVEF and the development of postoperative congestive heart failure after CABG.[11] On the contrary, LV dilatation after myocardial infarction results from expansion of the infarct area, an increase in the proportion of the surface area of the left ventricle occupied by necrotic

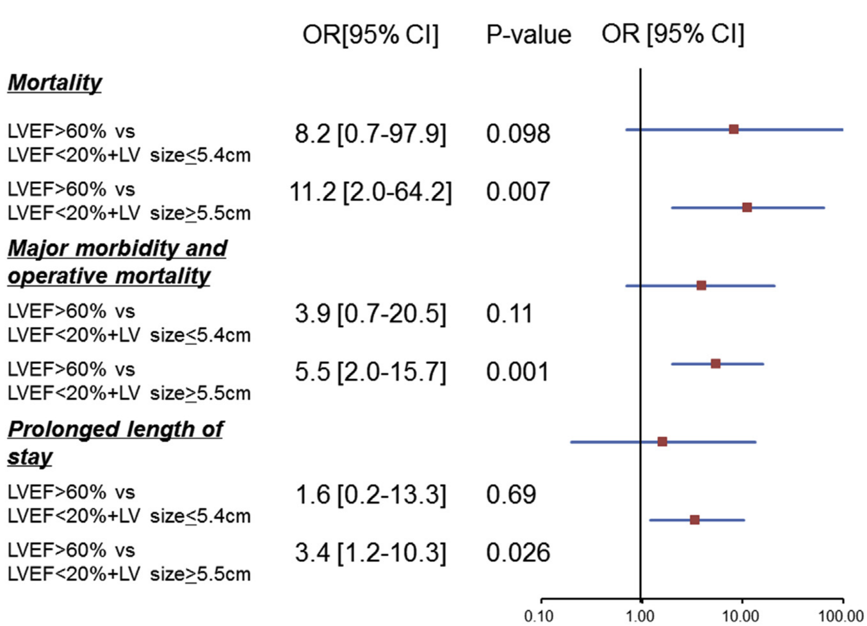

Figure 2. Forest plot showing the relative risk across groups for patients undergoing isolated coronary artery bypass grafting. Left ventricular ejection fraction (LVEF) greater than 60% is the reference. (CI, confidence interval; OR, odds ratio.)

myocardium with concomitant thinning of the infarcted wall, cavity dilatation, and distortion of the ventricle.[16] This finding suggests that a dilated left ventricle reflects irreversible changes in ischemic patients and LV size can be a parameter to predict outcomes.

Previously, our group reported early and long-term outcomes in patients with LVEF less than 20% and maximal oxygen consumption less than 14 mL/m^2 who were eligible for advanced therapies such as heart transplantation or ventricular assist device implantation. In-hospital mortality was 12%, and survival rates were 72 $\pm$ 4% at 5 years and 39 $\pm$ 8% at 10 years, which were comparable with those reported after advanced surgical therapies.[10] However, as in many other prior reports, we were unable to stratify outcomes on the basis of LV size.

In the present study, we focused on preoperative LV size combined with LVEF to investigate whether these combinations could improve patient risk stratification and predict outcomes after cardiac surgery. As expected, our results showed that the mortality rate was higher in patients with LVEF less than 20% vs LVEF greater than 60% irrespective of LV size. However, in those patients undergoing isolated CABG, the outcomes in the group of patients with LVEF less than 20% and LV size of 5.4 cm or smaller were comparable to those in patients with preserved LVEF.

White and colleagues[17] previously found that preoperative LV end-systolic volume was the best predictor of prognosis in patients with myocardial infarction treated medically. The addition of end-systolic volume for risk stratification clearly showed prognostic power over LVEF alone when LVEF was less than 50% or when the end-systolic volume was greater than 100 mL.[17] Hamer and colleagues[18] also analyzed the effect of LV end-systolic volume on survival in patients with an LVEF less than 40% who were undergoing CABG. These investigators concluded that LV end-systolic volume index was the strongest predictor of survival in these patients. In patients with an end-systolic volume of 95 mL or greater vs less than 95 mL, the relative risk for mortality was 1.15 (95% CI, 1.00 to 1.34).[18] Furthermore, Yamaguchi and colleagues[11] revealed that a preoperative end-systolic volume index >100 mL/m^2 predicted late mortality and development of congestive heart failure in patients with an LVEF less than 30% who were undergoing isolated CABG. These findings demonstrate the utility of end-systolic volume or volume index to predict postoperative courses in patients with severe LV dysfunction. Louie and colleagues[19] revealed LV end-diastolic dimension as 1 of the determinants of early and late death in patients with ischemic cardiomyopathy who underwent CABG. The LV end-diastolic dimension was 81 $\pm$ 4 mm in the failing CABG group and 68 $\pm$ 3 mm in the successful group ($P < .05$). When examining LVEF alone, there was no statistically significant difference between the failing and successful groups (15 $\pm$ 4% vs 26 $\pm$ 9%, respectively).[19]

When we analyzed our entire cohort, we were unable to demonstrate a relationship between LV size and perioperative outcomes. This is likely because of the differential effect of infarction (seen in CABG-treated patients) vs pressure or volume overload seen in patients with valve disorders. It is common to see LV remodeling after valvular surgery (particularly in the presence of corrected aortic or mitral insufficiency), yet it is rare to see nonsurgical remodeling in patients with ischemic cardiomyopathy. Therefore, it is logical that LV size has a more profound effect on isolated CABG procedures than in valvular operations.

Recent technologic advances and improvement in mechanical circulatory support provide patients who are ineligible for heart transplantation with improved late outcomes.[20] Combining preoperative LVEF and LV size in isolated CABG candidates may be a useful marker in the decision-making process for either conventional cardiac surgery or advanced therapies.

Our study has some important limitations. The first is that this study is retrospective. The second is that we did not compare assessments of LV size (end-systolic vs end-diastolic size) because of the small sample size. The third is that the number of participants with isolated CABG after propensity-score matching was small. The fourth is that only 46.1% of the patients with LVEF less than 20% had documented preoperative viability assessments. The lack of preoperative viability assessment in patients with LVEF less than 20% may have affected the choice of surgical strategies and postoperative outcomes. The fifth is that our study was analyzed by using categorical variables, rather than continuous variables. This is because we do not believe that a reported LVEF of 25% is materially different from 23% or 27%. Historically, our echocardiography laboratory provided a range of LVEF estimates (grade 1, LVEF >60%; grade 2, LVEF 40% to 59%; grade 3, LVEF 20% to 39%; and grade 4, LVEF <20%). More recently, a range of estimated LVEF is provided (ie, LVEF between 20% and 25%). To reduce unintentional variability and maintain a constant approach across time, we reported LV grade as a categorical variable in this study. We concede that the use of a continuous LVEF may be a more powerful statistical method, but it may also inaccurately differentiate between an LVEF of 25% and an LVEF of 27%.

In conclusion, perioperative outcomes in patients submitted to conventional cardiac surgeries with severe LV dysfunction (LVEF <20%) were significantly worse than in those with preserved LV function (LVEF >60%). LVEF continues to be an important predictor of outcome after cardiac surgery. In patients who are to undergo isolated CABG, LV size combined with LVEF could help predict postoperative outcomes and aid in the decision-making process to determine the optimal surgical strategy. Furthermore, public report cards that compare outcomes across institutions or surgeons should incorporate LV size into their risk adjustment models.

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Size Probably Matters

Invited Commentary:

In this issue of *The Annals of Thoracic Surgery*, Fukunaga and associates[1] analyze outcomes after cardiac surgery, comparing propensity-matched groups of patients with an ejection fraction (EF) of less than 20% vs those with an EF greater than 60%. They further stratified the severely depressed EF group by left ventricular (LV) size (less than vs greater than 5.4 cm). They found that EF was predictive of outcomes in all comers. However, LV enlargement did not offer further prognostic ability in patients with severely depressed EF. In the subgroup of patients undergoing coronary artery bypass grafting (CABG), EF was again predictive of outcomes. The poorer outcomes seen in CABG patients with severely depressed EF were confined only to those patients with LV enlargement, however.

The authors are to be congratulated for a very thought-provoking analysis and discussion of a ubiquitous dilemma faced by cardiac surgeons. Although EF is generally recognized as a powerful prognostic indicator after cardiac surgery, it is clear that, when viewed in isolation, it can be very misleading. Risk assessment scores utilizing EF generally underestimate risk in the severely depressed EF patients,[2] in whom erroneous judgment can be catastrophic. Given the rapidly expanding repertoire of percutaneous therapies for ischemic and valvular heart disease and mechanical circulatory support options, decision-making is even more complex. Predicting exactly which patients with severely depressed EF are of prohibitive risk for traditional cardiac surgical therapies is now of paramount importance as alternatives are readily available.

Nevertheless, several significant limitations exist in the current analysis. The authors' conclusion that LV size does not further differentiate outcomes in the overall cohort with severely depressed EF is tempered by the fact that there were only 36 patients with severely depressed EF and LV enlargement. Furthermore, in the CABG subgroup, only 33 and 11 patients had severely depressed EF without and with LV enlargement, respectively. The authors statement that "[CABG] patients with extreme LV dysfunction are not at significantly increased operative risk provided that they have not yet developed LV dilatation" is not supported by the data provided. In fact, mortality in patients with severely depressed EF without LV enlargement was increased 8.2-fold with a *P* value of .098 despite these extremely small numbers. Other limitations, including the retrospective nature of the study,

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