ADULT CARDIAC

Utility of a Simple Algorithm to Grade Diastolic Dysfunction and Predict Outcome After Coronary Artery Bypass Graft Surgery

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Background. **Inclusion of a measure of left ventricular diastolic dysfunction (LVDD) may improve risk prediction after cardiac surgery. Current LVDD grading guidelines rely on echocardiographic variables that are not always available or aligned to allow grading. We hypothesized that a simplified algorithm involving fewer variables would enable more patients to be assigned a LVDD grade compared with a comprehensive algorithm, and also be valid in identifying patients at risk of long-term major adverse cardiac events (MACE).**

Methods. **Intraoperative transesophageal echocardiography data were gathered on 905 patients undergoing coronary artery bypass graft surgery, including flow and tissue Doppler-based measurements. Two algorithms were constructed to categorize LVDD: a comprehensive four-variable algorithm, A, was compared with a simplified version, B, with only two variables—transmitral early flow velocity and early mitral annular tissue velocity—for ease of grading and association with MACE.**

Results. **Using algorithm A, only 563 patients (62%) could be graded, whereas 895 patients (99%) received a grade with algorithm B. Over the median follow-up period of 1,468 days, Cox modeling showed that LVDD was significantly associated with MACE when graded with algorithm B (p = 0.013), but not algorithm A (p = 0.79). Patients with the highest incidence of MACE could not be graded with algorithm A.**

Conclusions. **We found that an LVDD algorithm with fewer variables enabled grading of a significantly greater number of coronary artery bypass graft patients, and was valid, as evidenced by worsening grades being associated with MACE. This simplified algorithm could be extended to similar populations as a valid method of characterizing LVDD.**

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Left ventricular diastolic dysfunction is a ubiquitous finding in congestive heart failure, may frequently be the sole abnormality in these patients, and is an independent predictor of adverse outcome [1, 2]. Incorporation of some measure of impaired diastolic function has also been suggested to improve the accuracy of cardiac surgery risk prediction models [3]. Although there are echocardiographic criteria for characterizing diastolic dysfunction, these guidelines are based on transthoracic echocardiography. Moreover, data pertaining to diastolic function using transesophageal echocardiography (TEE) are fairly limited, and intraoperative assessment of diastolic function remains challenging [4–7].

The recommended algorithm for grading diastolic dysfunction includes echocardiographic measurements that reflect impaired diastolic physiology [8]. The algorithm itself is conditional on the simultaneous presence of measurements within specific ranges. It is possible that some patients may not be assigned a grade if echocardiographic measurements are not aligned. Moreover, load-dependent measurements, such as transmitral flow, may not reflect true diastolic patterns owing to intraoperative hemodynamic variability. Recognizing the limitations of a comprehensive grading algorithm, the American Society of Echocardiography (ASE) suggests that a simplified grading approach with high feasibility and reproducibility may be preferable in the clinical setting [8]. Moreover, a simplified approach is highly desirable intraoperatively owing to the limited time frame for TEE examination. However, any grading system, regardless of simplicity, is irrelevant unless it provides prognostic information by identifying those at risk of adverse outcomes.

The feasibility of applying a comprehensive algorithm for grading diastolic dysfunction has not been assessed in cardiac surgery patients, and neither has its prognostic significance been determined. In a population of patients

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undergoing coronary artery bypass graft (CABG) surgery, we hypothesized that a simplified grading algorithm will allow diastolic function to be graded on a larger proportion of patients when compared with a comprehensive algorithm. Additionally, we determined the ability of each algorithm to identify those most at risk by examining the association of derived diastolic dysfunction grade with long-term major adverse cardiac events (MACE).

Patients and Methods

Patient Selection and Data Sources

After approval by the Duke University Institutional Review Board, detailed clinical and intraoperative TEE data were gathered for all adult cardiac surgical patients at our institution from January 1, 2002, to December 31, 2006.

A protocol for diastolic function assessment was implemented for all patients undergoing cardiac surgery and TEE examination in 2001. The long-term objective was to gather data on echocardiographic determinants of diastolic function to eventually determine the significance of diastolic dysfunction in cardiac surgery. To test our principal hypothesis, specific exclusions were applied to the entire population to obtain a more homogenous cohort with consistent echocardiographic data.

Only patients undergoing isolated CABG surgery performed using cardiopulmonary bypass with complete intraoperative TEE data were identified for inclusion as the study cohort. Patients dependent preoperatively on electrical pacing, inotropes, or intraaortic balloon pump support were excluded. Anesthesia and surgery were managed per institutional protocol and have been previously described [9, 10].

Data were sourced from the Duke Databank for Cardiovascular Diseases, a large, quality-assured database that prospectively gathers demographic, periprocedural, and follow-up data for all cardiovascular interventions performed at Duke University.

Echocardiographic Assessment of Diastolic Function

Intraoperative TEE was performed according to published guidelines on all patients [11] Diastolic function was assessed according to a protocol using three modalities: (1) spectral pulsed wave Doppler of transmitral inflow, (2) pulsed wave Doppler profile of pulmonary venous flow, and (3) spectral tissue Doppler imaging of diastolic myocardial velocity at the lateral mitral annulus. A summary of views and measurements is provided in Table 1.

All TEE studies were performed by an attending cardiac anesthesiologist in concert with a cardiac anesthesia fellow in a dedicated perioperative echocardiography training program. Measurements pertaining to diastolic function were obtained on each patient at baseline, after induction of anesthesia. Spectral recordings were made at end expiration, when feasible, at a sweep speed of 50 to 100 mm/s depending on heart rate. Measurements were not averaged over several cycles, but the most representative waves were chosen for measurements. Inconsistent waveforms, for example, due to fluctuating hemodynamics, were excluded from measurement.

Table 1. Summary of Imaging Views and Doppler Measurements for Diastolic Function Assessment

Modality and View	Measurements	Units
Transmitral flow (TMF)	Peak early velocity (E)	cm/s
Midesophageal four-chamber view	Peak late velocity (A)	cm/s
	E-wave deceleration time (DT)	ms
	A duration (Adur)	ms
Pulmonary venous flow (PVF)[a]	Peak systolic velocity (S)	cm/s
	Peak diastolic velocity (D)	cm/s
	Peak atrial reversal velocity (AR)	cm/s
	AR duration (ARdur)	ms
Tissue Doppler imaging (TDI)	Peak early velocity (e′)	cm/s
Midesophageal four-chamber view	Peak late velocity (a′)	cm/s

[a] Nonstandard view modified from midesophageal four-chamber at 30 degrees with probe anteflexed to view left superior pulmonary vein adjacent to left atrial appendage.

According to the protocol, diastolic function was not measured if it was determined by the clinical care team that patients were hemodynamically unstable, had a heart rate that was high enough to preclude accurate diastolic measurements, had any dysrhythmia, or required acute clinical care precluding time for detailed Doppler examination. This decision was at the discretion of the clinical team. Therefore, patients with incomplete or missing data were excluded from analyses.

All measurements were made in real-time and their accuracy verified offline by an independent, board-certified echocardiographer blinded to grading algorithm and outcome.

Follow-Up and Outcomes

Follow-up was conducted by the Duke Clinical Research Institute Follow-up Services Group, and has been previously described [12]. Briefly, this group is responsible for collecting annual follow-up mortality data and nonfatal endpoint information for the Duke Databank for Cardiovascular Diseases. The annual surveys collect data 6 months after an index visit and yearly thereafter. Follow-up is 95% complete for mortality, and patients who are lost to follow-up (2%) or who have asked to be withdrawn (3%) are submitted for an annual search of the National Death Index. Cause of death is assigned after agreement from independent reviews by an adjudication committee.

The primary outcome measure was defined as MACE, a composite index of myocardial infarction, need for subsequent surgical or percutaneous coronary revascularization, or death (all-cause mortality) during the follow-up period. The Duke Databank for Cardiovascular Diseases uses The Society of Thoracic Surgeons data definitions, which defines postoperative myocardial infarction if two of the following four criteria are met: (1) prolonged (longer than 20 minutes) typical chest pain not relieved by rest or nitrates; (2) elevation of either creatinine kinase–isoenzyme myocardial band by more than 5% of total creatinine kinase, creatinine kinase greater than two times normal, lactate dehydrogenase subtype 1 greater than lactate dehydrogenase subtype 2, or troponin greater than 0.2 $\mu g \cdot L^{-1}$; (3) new postoperative wall motion abnormalities; (4) serial electrocardiograms (at least two) showing changes from baseline or serially in ST-T or Q waves, or both, that are 0.03 s in width or more than or plus one third of the total QRS complex in two or more contiguous leads. For patients with more than one event (MI or revascularization), only the time to the first event was recorded.

Statistical Approach

There were a total of 2,904 isolated on-pump CABG procedures performed during the study period. After data extraction for all echocardiographic measurements, there were 905 patients with complete data available. After independent verification of accuracy, we determined the number of patients who could be assigned a diastolic dysfunction grade based on the guidelines recommended by the ASE (Fig 1) [8]. The original guidelines were modified to exclude left atrial volume, septal tissue velocity, and Valsalva-based measurements. These measurements have neither been validated nor have precedents in the intraoperative setting. Diastolic dysfunction was graded in all 905 patients using the echocardiographic measurements obtained as grade 0 (normal function), grade 1 (impaired relaxation), grade 2 (pseudonormal), or grade 3 (restrictive).

ALGORITHM A. As stated in our a priori hypothesis, our objective was to compare a comprehensive algorithm A that required all measurements to be aligned for grade assignment with a simplified algorithm B that included a limited number of measurements. However, using the comprehensive approach for algorithm A, whereas 158 patients were classified as normal, only 22 patients could be characterized as grade 1, 3 patients as grade 2, and 1 patient as grade 3 diastolic dysfunction, leaving 721 (80%) cases uncategorized. It was clear that this grading approach would not allow (1) diastolic dysfunction to be characterized in a vast majority of cases, or (2) risk of adverse outcome to be determined. We, therefore, modified our grading approach for algorithm A with the following approach: in the event that the tissue Doppler imaging e′ velocity was less than 10 cm/s, at least two rather than all four variables (Fig 1) had to be aligned for a diastolic dysfunction grade to be assigned. Patients who could not meet this requirement were not graded and, therefore, were excluded from analysis.

ALGORITHM B. In this simplified algorithm, diastolic dysfunction was graded based only on the e′ velocity (less than or greater than 10 cm/s) and transmitral E to e′ ratio (Fig 1, shaded area).

ANALYSIS. After grade assignment, we determined the proportion of the sample that was able to be graded with each algorithm. Next, to determine the most clinically relevant algorithm, we tested the independent association of each algorithm with MACE in two separate multivariable Cox proportional hazards models. Diastolic dysfunction in each model was considered as a categorical variable including all four grades. Each model was adjusted for cardiopulmonary bypass (CPB) time and the European System for Cardiac Operative Risk Evaluation (EuroSCORE), a validated method of mortality risk prediction in cardiac surgery [13]. Freedom from MACE was assessed by constructing survival curves for both models using the Kaplan-Meier method. Individual MACE-free survival curves were compared using the log rank test. All analyses were conducted using SAS statistical software, version 9.1.3 (SAS Institute, Cary, NC). Significance was assessed at a p value of less than 0.05.

Results

Complete echocardiographic data that allowed grading of diastolic function were available in 905 patients. De-

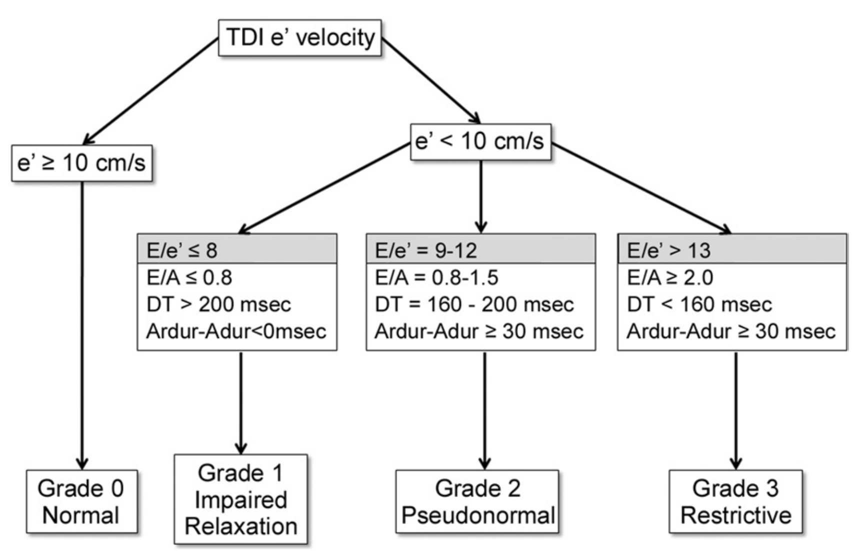

Fig 1. Algorithms used for grading diastolic dysfunction. For abnormal grades of diastolic dysfunction (grades 1 to 3), algorithm A included all indicated variables whereas algorithm B included only those within the shaded area. (A = transmitral diastolic A wave; Adur = transmitral A-wave duration; Ardur = pulmonary vein flow A reversal wave duration; DT = E-wave deceleration time; E = transmitral early wave; e′ = lateral mitral annular early diastolic tissue velocity; TDI = tissue Doppler imaging.)

Table 2. Demographic Characteristics of the Study Population

Variable	No. of Patients in Sample	Value
Age, years	897	63.7 (10.2)
Percent female	897	18.8%
Caucasian, %	897	74.6%
Congestive heart failure	897	18.1%
Hypertension	897	75.7%
Diabetes mellitus	897	35.2%
Weight, kg	787	90.0 (23.6)
Ejection fraction, %	779	55.6
Smoking history	897	42.3%
Renal disease[a]	897	3.5%
Preoperative dialysis	897	2%
COPD	897	12.2%
Previous MI	897	56.6%
EuroSCORE	812	8.4 (3.2)
Cardiopulmonary bypass time, minutes	890	128.8 (63.7)
Aortic cross-clamp time, minutes	716	74 (26.6)
In-hospital mortality	890	2.1%
One-year mortality	890	7.4%

Values are expressed as a percentage of the population, or as mean ± SD in parentheses as indicated. [a] Renal disease defined as a baseline (preoperative) creatinine greater than 2.0 mg/dL.

COPD = chronic obstructive pulmonary disease; EuroSCORE = European System for Cardiac Operative Risk Evaluation; MI = myocardial infarction.

mographic characteristics of the study population are provided in Table 2. Follow-up data were available for 890 patients (98%), with a median follow-up period of 1,468 days, during which there were 252 MACE events.

With algorithm A, 563 patients (62%) received a grade of diastolic dysfunction. In contrast, with the simplified algorithm B, 895 patients (99%) were assigned a grade. Detailed grade distribution for each algorithm is provided in Table 3.

In the principal multivariable analysis, grading of diastolic dysfunction using algorithm A was not significantly associated with MACE ($p = 0.79$) in a model adjusted for EuroSCORE and CPB time. Kaplan-Meier survival curves did not show a significant difference among the different grades and event-free survival (Fig 2). In the group of 38% of patients who could not be assigned any grade of diastolic dysfunction, MACE-free survival was significantly lower when compared with the rest of the cohort who could be categorized ($p = 0.005$; hazard ratio 0.699; 95% confidence interval: 0.54 to 0.90). Therefore, using this algorithm, we were (1) unable to grade a substantial proportion of patients, and (2) patients who were graded were not at highest risk of MACE, highlighting the inability of this approach to identify those most at risk.

The second Cox proportional hazards regression model showed that grading according to the simplified algorithm B was significantly associated with MACE ($p = 0.013$). The significance was for a three degree-of-freedom test including all four grades of diastolic dysfunction. As shown in Table 4, with grade 3 (restrictive) as a reference value, each grade of diastolic dysfunction

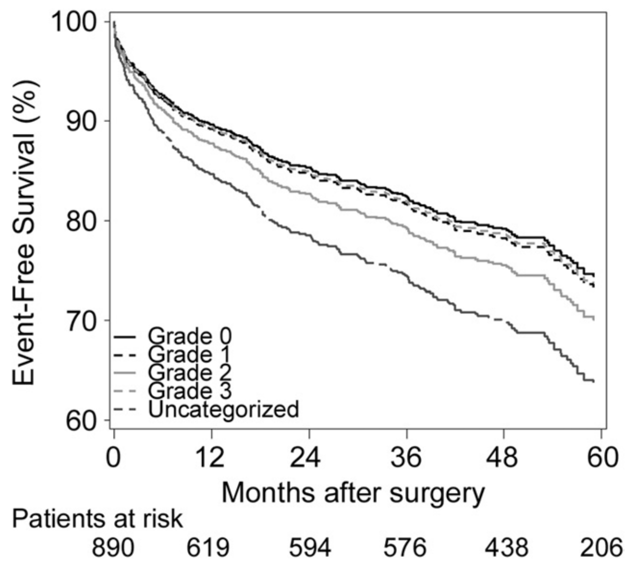

Fig 2. Survival curves for major adverse cardiac events (MACE) are shown using the Kaplan-Meier method for patients grouped according to grade of diastolic dysfunction using algorithm A. An additional survival curve shows lower MACE-free survival for patients unable to be assigned a grade with this algorithm (uncategorized). Overall p value for comparing the categorized groups is not significant (p = 0.079). However, the uncategorized group shows significantly lower MACE-free survival compared with categorized patients (p = 0.005).

Table 3. Distribution of Diastolic Dysfunction Grade in Each Algorithm

Diastolic Dysfunction Grade	Algorithm A (n = 563)	Algorithm B (n = 895)
Grade 0 (normal)	158 (28%)	158 (18%)
Grade 1 (impaired relaxation)	152 (27%)	309 (34%)
Grade 2 (pseudonormal)	200 (36%)	267 (30%)
Grade 3 (restrictive)	53 (9%)	161 (18%)

Table 4. Cox Proportional Hazards Model for Factors Associated With Long-Term Major Adverse Cardiac Events[a]

Variable	*p* Value	Hazard Ratio	95% Confidence Limits
Grade 0	0.008	0.56	0.36–0.86
Grade 1	0.004	0.61	0.43–0.85
Grade 2	0.038	0.70	0.51–0.98
EuroSCORE	<0.0001	1.08	1.04–1.12
CPB time	0.002	1.00	1.00–1.01

[a] Including diastolic dysfunction categorized in four grades with algorithm B using grade 3 as a reference group. The model is also adjusted for European System for Cardiac Operative Risk Evaluation (EuroSCORE) and cardiopulmonary bypass (CPB) time.

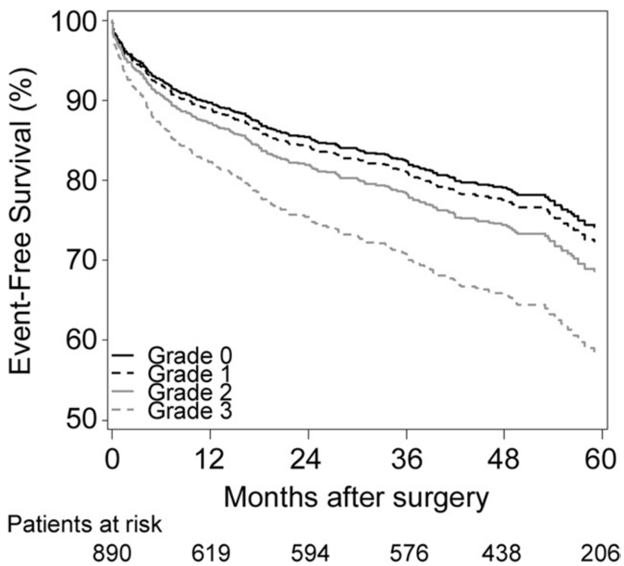

Fig 3. Survival curves for major adverse cardiac events (MACE) are shown using the Kaplan-Meier method for patients grouped according to grade of diastolic dysfunction using algorithm B. Worsening diastolic dysfunction is significantly associated with decreased MACE-free survival (overall p value for comparison of categorized groups is significant at 0.01).

was negatively associated with MACE. The EuroSCORE and the CPB time were also significantly associated with the outcome in this model. Kaplan-Meier survival curves showed that each grade of increasing diastolic dysfunction was associated with a higher risk of MACE (Fig 3).

To assess the significance of the E/e′ ratio as a prognostic indicator, we examined the independent association of E/e′ ratio as a continuous variable with MACE as the outcome of interest. This secondary analysis showed that E/e′ ratio was significantly associated with long-term MACE in a model adjusted for EuroSCORE and CPB time ($p = 0.0015$).

Comment

This study examined the applicability and clinical value of two grading algorithms for establishing the severity of diastolic dysfunction in a large population of patients undergoing CABG surgery. We confirmed our hypothesis that a simplified grading algorithm permits diastolic dysfunction categorization in a larger proportion of patients compared with the more rigorous criteria. In addition, the simplified algorithm has improved prognostic value for long-term adverse outcome, and was able to identify those at highest risk. This simplified approach could enable diastolic dysfunction to be more accurately characterized in more patients with relevance to clinical outcomes.

Diastolic dysfunction portends a poor prognosis in patients with congestive heart failure. Accordingly, it has been the subject of several investigations, many of which have focused on echocardiographic techniques for improved classification and detection. Although a number of studies have explored diastolic dysfunction with perioperative TEE, they have been limited either in scope or in number of patients studied [6, 14, 15]. Nevertheless, these investigations have proved valuable for establishing feasibility of detecting intraoperative diastolic dysfunction with TEE. Studies have also reported perioperative changes in diastolic function by TEE and the impact of pharmacologic intervention on perioperative diastolic function [14–18]. Whereas two groups examined several echocardiographic measures of diastolic function that were similar to our study, their cumulative subject populations were limited to 74 patients, and outcome was not studied [14, 15]. Studies on the effects of commonly used inotropes such as milrinone and epinephrine on the diastolic properties of the heart during cardiac surgery have reported mixed results, and the diastolic effects of some of these drugs, such as milrinone, remain unclear [16–18]. A lack of consistency in the approach to characterization of diastolic dysfunction may have contributed to the disagreement among studies.

Recently, Flu and colleagues [19] examined adverse cardiovascular outcomes in 1,005 patients undergoing vascular surgery and found that isolated diastolic dysfunction was independently predictive of adverse outcome. Although their study examined vascular surgery cases and used transthoracic echocardiography to examine diastolic function, this report adds to the evidence that perioperative diastolic dysfunction is an important variable for risk stratification. In another study, Matyal and colleagues [7] first determined the presence of diastolic dysfunction and then examined its impact on adverse postoperative outcome of 313 patients undergoing major vascular surgery. They reported that diastolic dysfunction was present in two thirds of their population, and was independently predictive of adverse outcome. This study defined diastolic dysfunction as a binary variable using a single metric (flow propagation velocity threshold value of 45 cm/s), which has inherent limitations and cannot identify advanced grades of diastolic dysfunction. In contrast, our study incorporated guidelines for grading diastolic function using multiple measures in a larger CABG cohort. We were therefore able to characterize diastolic function in greater detail with two separate algorithms that could be used to cross-validate our findings in other surgical populations.

Our study is strengthened by the inclusion of a large homogenous population, a protocol-driven comprehensive TEE examination, and the use of quality-assured data sources and robust follow-up methodology. The results are, however, limited by the retrospective nature of data collection. However, our protocol was established before data collection with the explicit intent to study diastolic dysfunction. Knowledge of recommended grading algorithms did not exist at the time of assessment, thereby precluding bias at the time of data collection. Not all patients undergoing CABG surgery had echocardiographic assessment of diastolic function. The protocol prioritized clinical care over diastolic function assessment, leading to exclusion of some patients without diastolic measurements. Therefore, it is possible that some cases with true diastolic dysfunction and more frequent MACE may have been missed as they did not have adequate data to be categorized according to algorithm A. In addition, patients with regional ischemia may have had reduced e′ velocities disproportionate to global diastolic impairment. However, the measurement of e′ at the lateral mitral annulus is a standard technique that is recommended for assessment of LV diastolic function, and a separate recommendation for global diastolic function measurement does not exist.

The original ASE recommended approach was modified owing to lack of standardized methods for some measurements such as left atrial volume assessment by TEE [8]. The ASE recommendations for chamber quantification do not include TEE-based assessment of left atrial volume [20]. Moreover, using TEE, a part of the left atrium may be excluded from view in most midesophageal views owing to the close proximity of the esophagus with the left atrium [11]. Loading conditions can be altered under anesthesia and the TEE-based measurements may not reflect the usual awake state. Although we did not include hemodynamic data, the measurements we made were protocol driven and standardized in all patients. It is likely that the effect of any changes in preload would be randomly distributed across the study population. We did not repeat measurements using different observers or with the same observer; hence, we lack the validation of intraobserver and interobserver variability. However, to improve accuracy, all measurements were verified offline by an independent observer blinded to grading algorithm.

We were unable to apply the entire ASE-recommended algorithm to most of our study population. Even when we substantially relaxed the number of determinants required for grading (algorithm A), we could not characterize diastolic function in 38% of patients. In addition, this algorithm excluded patients most at risk of adverse outcome. The requirement of several measurements to be within a specific range reduces the likelihood of satisfactory categorization of diastolic dysfunction. Several patients only partially met categorization requirements of algorithm A. The following hypothetic patient illustrates this concept: a patient has an e′ velocity of 8 cm/s, an E velocity of 40 cm/s, an A velocity of 30 cm/s, and an E-wave deceleration time of 190 ms. The E/e′ ratio is 5, and the E/A ratio is 1.3. According to algorithm A, this patient would not receive a grade of diastolic dysfunction because the variables are not aligned to any single grade. In contrast, with algorithm B, this patient would be deemed to have grade 1 diastolic dysfunction by virtue of an e′ velocity less than 10 cm/s and an E/e′ ratio less than 8. The simplified algorithm would not only enable diastolic function categorization for this patient, but would also assist with outcome prognostication. It could be argued that such a hypothetic situation is not realistic since echocardiographic measurements should be aligned according to the categorization scheme. However, in the setting of cardiac surgery and altered loading conditions, measurements that are sensitive to preload may force misalignment of the algorithm components, thereby precluding accurate categorization. Our results support the use of E/e′ ratio as it was found to be independently associated with long-term adverse outcome. The contribution of diastolic dysfunction to postoperative mortality should be assessed with other known components of the EuroSCORE or the STS risk index in a larger and more diverse cohort of cases. Either the E/e′ ratio or the proposed simplified algorithm could then be included in these risk predictive models.

In summary, we found that a simple scheme, including only two echocardiographic measurements—the peak transmitral E velocity and the peak lateral mitral annular myocardial e′ velocity—permits characterization of diastolic dysfunction in a majority of patients undergoing CABG surgery. Additionally, this grading approach identifies patients most at risk of adverse long-term outcomes. Further research is warranted to determine whether this algorithm is generalizable across different populations, and to identify modifiable factors associated with worsening of diastolic function to improve postoperative outcomes.

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Appendix 1

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INVITED COMMENTARY

Diastolic dysfunction refers to aberrant diastolic distensibility, filling, or relaxation of the left ventricle, regardless of whether the ejection fraction is normal or abnormal, asymptomatic, or symptomatic [1]. Population-based studies have shown that approximately a third of heart failure patients have normal or near-normal ejection fraction [2]. The prevalence of diastolic heart failure is highest among the hypertensive, diabetic, interstitial cardiomyopathies especially ventricular hypertrophy, as well as those in the seventh decade of life or older [1]. There is epidemiologic evidence that survival improved among patients with reduced ejection fraction, whereas it did not improve among patients with preserved ejection fraction.

Although the exact pathologic process for diastolic dysfunction is unknown, inflammatory cytokines, osteopontin, and the fibroblast have been proposed. Despite these findings, diastolic dysfunction in the surgical arena remains somewhat elusive due to (1) the lack of one true definition (mitral valve inflow pulse wave Doppler, pulmonary vein flow Doppler, and mitral annular tissue Doppler velocities, which are usually septal and lateral annular velocities) and (2) the difficulty in objectively assessing efficacy of available therapies. The presence of diastolic dysfunction can alert the patient's physician and surgeon of potential suboptimal ventricle performance. However, what does this really mean prior to revascularization of an ischemic myocardium?

The excellent article by Swaminathan and colleagues [3] in this issue of *The Annals of Thoracic Surgery* used a simplified and modified algorithm to assign diastolic dysfunction grade in the operating room with transesophageal echocardiography. This group elegantly illustrated sound correlation of diastolic grade and long-term risk of major adverse cardiac events. In physiologic terms, the ventricular wall tension is increased, placing more risk on the perfusion-sensitive subendocardium of an already ischemic heart. Furthermore, limitation of coronary perfusion, in the face of the critical perioperative period, and suboptimal revascularization can provide a substrate for hemodynamic compromise and overt ventricular failure. This may further explain the finding of greater loss of life with greater degree of diastolic dysfunction up to many years in the cohort. Hemodynamic loading and heart rate need to be defined before quantitatively grading diastolic dysfunction in the operating room. Unanswered in this study, but what should be investigated relates to the influence of the long-term effect of total revascularization versus subtotal revascularization on diastolic function recovery (ie, increased bypass target sites). Furthermore, left ventricular dia-

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