Anesthesiology 2010; 112:1316–24

Prognostic Implications of Asymptomatic Left Ventricular Dysfunction in Patients Undergoing Vascular Surgery

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ABSTRACT

Background: The prognostic value of heart failure symptoms on postoperative outcome is well acknowledged in perioperative guidelines. The prognostic value of asymptomatic left ventricular (LV) dysfunction remains unknown. This study evaluated the prognostic implications of asymptomatic LV dysfunction in vascular surgery patients assessed with routine echocardiography.

Methods: Echocardiography was performed preoperatively in 1,005 consecutive vascular surgery patients. Systolic LV dysfunction was defined as LV ejection fraction less than 50%. Ratio of mitral-peak velocity during early and late filling, pulmonary vein flow, and deceleration time was used to diagnose diastolic LV dysfunction. Troponin-T measurements and electrocardiograms were performed routinely perioperatively. Multivariate regression analyses evaluated the relation between LV function and the study endpoints, 30-day cardiovascular events, and long-term cardiovascular mortality.

Results: Left ventricular dysfunction was diagnosed in 506 (50%) patients of which 80% were asymptomatic. In open vascular surgery (n = 649), both asymptomatic systolic and isolated diastolic LV dysfunctions were associated with 30-day cardiovascular events (odds ratios 2.3, 95% confidence interval [CI] 1.4–3.6 and 1.8, 95% CI 1.1–2.9, respectively) and long-term cardiovascular mortality (hazard ratios 4.6, 95% CI 2.4–8.5 and 3.0, 95% CI 1.5–6.0, respectively). In endovascular surgery (n = 356), only symptomatic heart failure was associated with 30-day cardiovascular events (odds ratio 1.8, 95% CI 1.1–2.9) and long-term cardiovascular mortality (hazard ratio 10.3, 95% CI 5.4–19.3).

Conclusions: This study demonstrated that asymptomatic LV dysfunction is predictive for 30-day and long-term cardiovascular outcome in open vascular surgery patients. These data suggest that preoperative risk stratification should include not only solely heart failure symptoms but also routine preoperative echocardiography to risk stratify open vascular surgery patients.

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Received from the Department of Anesthesiology, Erasmus Medical Center, Rotterdam, The Netherlands. Submitted for publication November 4, 2009. Accepted for publication February 4, 2010. Supported by an unrestricted grant from "lijf en leven" Foundation, Rotterdam, South Holland, The Netherlands (to Drs. Flu, van Kuijk, Hoeks, and Goei). The results from this study have been presented at the annual congress of the European Society of Cardiology, September 2, 2009, Barcelona, Spain. The study population has been previously described in a manuscript (*European Journal of Heart Failure* 2010; 12:288–93, included as reference 10 in this manuscript) addressing the prevalence of left ventricular dysfunction in vascular surgery patients and pharmacologic treatment as recommended in the most recent European Society of Cardiology guidelines for the diagnosis and treatment of heart failure. The new finding and central topic of this study constitute the prognostic implications of asymptomatic diastolic/systolic left ventricular dysfunction patients undergoing endovascular or open vascular surgery.

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◇ This article is featured in "This Month in Anesthesiology." Please see this issue of ANESTHESIOLOGY, page 9A.

◆ This article is accompanied by an Editorial View. Please see: Groban L, Kitzman DW: Diastolic function: A barometer for cardiovascular risk? ANESTHESIOLOGY 2010; 112:1303–6.

What We Already Know about This Topic

- Symptomatic heart failure is a recognized risk factor for postoperative morbidity after noncardiac surgery, but asymptomatic heart failure has not been examined

What This Article Tells Us That Is New

- In more than 1,000 patients undergoing vascular surgery, nearly 40% of patients have asymptomatic left ventricular failure and this doubled the risk of 30-day cardiovascular morbidity and quadrupled the risk of long-term mortality
- Routine preoperative echocardiography might be considered for patients undergoing open vascular procedures

WORLDWIDE, about 100 million adults undergo noncardiac surgery every year,[1] and by the year 2020 this number will increase by 25%.[2] The risk of adverse perioperative cardiovascular (CV) events after vascular surgery is particularly high as compared with other noncardiac surgeries.[3] Although ischemic heart disease is acknowledged to be the most important risk factor for CV after noncardiac surgery, several studies indicate that symptomatic heart failure is equally important.[4–6] In the general population, the prevalence of symptomatic heart failure is estimated to be around 2–3% and increases with age, with a prevalence estimated between 10% and 20% in septo- and octogenarians.[7] Although the term heart failure describes a clinical syndrome, left ventricular (LV) dysfunction describes the impaired mechanical properties of the left ventricle. Asymptomatic LV dysfunction is considered a precursor of symptomatic heart failure, associated with high mortality.[7] The prevalence of patients with asymptomatic LV dysfunction and symptomatic heart failure is assumed to be similar.[8]

In the most recent American College of Cardiology/American Heart Association and European Society of Cardiology perioperative guidelines,[3,9] the prognostic value of symptomatic heart failure on postoperative outcome is well acknowledged. However, the prognostic implications of asymptomatic LV dysfunction remain unknown. Routine perioperative evaluation of LV function is not recommended in the American College of Cardiology/American Heart Association perioperative guidelines (Class III, Level of Evidence: C).[9] In addition, LV assessment with rest echocardiography is not recommended in the European Society of Cardiology perioperative guidelines (Class III, Level of Evidence: C) for asymptomatic patients.[3]

We conducted this study to evaluate the impact of asymptomatic, isolated diastolic and asymptomatic systolic LV dysfunction, evaluated with routine preoperative echocardiography, on postoperative outcome of patients undergoing open or endovascular surgery.

Materials and Methods

Study Population

The study population has been previously described and consisted of 1,005 consecutive vascular surgery patients undergoing elective (open or endovascular) lower extremity artery, carotid artery, or abdominal aorta repair.[10] This prospective cohort study was performed at the Erasmus Medical Center in Rotterdam, The Netherlands, during the period of 2002–2008. The study was approved by the ethics committee of the hospital, and written informed consent was obtained from all patients.

Baseline Characteristics

Before surgery, a detailed history was obtained from every patient. Cardiac history was assessed, and ischemic heart disease was defined as a history of angina pectoris, coronary revascularization, or myocardial infarction. Additional clinical data included age, gender, blood pressure, heart rate, cerebrovascular disease (history of ischemic or hemorrhagic stroke), renal dysfunction (serum creatinine > 2 mg/dL), diabetes mellitus (fasting blood glucose ≥ 126 mg/dL or requirement of antidiabetic medication), hypertension (blood pressure $\geq 140/90$ mmHg in nondiabetics and $\geq 130/80$ mmHg in diabetics,[11] or requirement of antihypertensive medication), hypercholesterolemia (low-density lipoprotein cholesterol ≥ 135 mg/dL or requirement of lipid-lowering medication), chronic obstructive pulmonary disease (according to the Global Initiative on Obstructive Lung Diseases classification), and smoking status. Finally, the use of β-blockers, statins, aspirin, oral anticoagulants, angiotensin-converting enzyme inhibitors, angiotensin-receptor blockers, diuretics, and nitrates was recorded.

Echocardiography

Preoperatively, transthoracic echocardiography was performed in all patients using a portable Acuson Cypress Ultrasound System (Acuson; A Siemens Company, Mountain View, CA) with a 3V2C transducer (3.0/3.5/2.5/2.0 MHz) for adult cardiac evaluation. Standard parasternal and apical two- and four-chamber views were obtained during rest with the patient in the left lateral decubitus position as recommended.[12] Left ventricular end-systolic and end-diastolic volumes were determined, and LV ejection fraction was calculated using the biplane Simpson's technique,[13] with an inter- and intraobserver variability of 9–12% and 6%, respectively.[14] Systolic (S) and diastolic (D) pulmonary vein flow, deceleration time, and ratio of mitral peak velocity of early filling (E) to mitral peak velocity of late filling (A) were determined in apical four-chamber. Echocardiographic data were for research purposes and were not used for clinical management.

Definition of LV Dysfunction

Left ventricular ejection fraction less than 50%, both with and without accompanying diastolic dysfunction, defined systolic LV dysfunction.[7] Diastolic LV dysfunction was confirmed in patients with E/A ratio less than 0.8 (impaired relaxation) or more than 2 (restrictive relaxation).[15] Abnormal pulmonary vein flow ($S/D < 1$) was used to distinguish normal and pseudonormal diastolic LV function in patients

with E/A ratio between 0.8 and 2.[16] Deceleration time more than 220 ms (impaired relaxation) or less than 140 ms (restrictive relaxation) was defined as diastolic LV dysfunction in patients with atrial fibrillation.[16] Diastolic LV dysfunction, in the presence of an LV ejection fraction $\geq$ 50%, defined asymptomatic isolated diastolic dysfunction. The presence of LV dysfunction in combination with heart failure symptoms (shortness of breath, fatigue, exercise intolerance, signs of fluid retention) was defined as symptomatic heart failure.[7] Two experienced investigators performed offline assessments of the obtained ultrasound images. When there was disagreement between the two assessors, a third investigator viewed the images without knowledge of the previous assessment, and a majority decision was reached.

Study Outcomes

Serial electrocardiograms and troponin-T measurements were obtained from all patients before surgery, postoperatively on days 1, 3, and 7, and before discharge. Study endpoints were 30 days CV, defined as myocardial ischemia, myocardial infarction, and CV mortality, and long-term CV mortality. Myocardial ischemia was present in patients with normal preoperative and increased ($>$ 0.03 ng/ml) troponin-T levels postoperatively.[17] Elevated troponin-T levels in combination with electrocardiographic changes (new-onset ST-T changes and pathologic Q waves) defined myocardial infarction.[18] Troponin T level was measured using a whole blood rapid test (TropT version 2; Roche Diagnostics, Mannheim, Germany). Patients with elevated troponin-T levels before surgery were not included in the study. Patients were subjected to a follow-up visit with one of the study investigators 30 days postsurgery, and for those patients who did not attend, we approached the referring physicians. In patients still admitted or readmitted at the Erasmus MC, 30-day follow-up was completed using the Erasmus MC medical records.

Long-term mortality was assessed by approaching the municipal civil registries. Cause of death was ascertained by examining death certificates, and otherwise by reviewing medical records. Cause of death was classified as either cardiovascular or noncardiovascular death. Cardiovascular death was defined as any death with a cerebrocardiovascular complication as the primary or secondary cause and includes death after myocardial infarction, serious cardiac arrhythmias (defined as the presence of a sustained cardiac rhythm disturbance that required urgent medical intervention), congestive heart failure, stroke (cerebrovascular event or transient ischemic attack), and surgery-related bleeding complications (only a postoperative cause of death). Sudden unexpected death was classified as cardiovascular death. Cause of death was separately assessed by two authors. In the absence of consensus, a third investigator assessed the cause of death and a majority decision was reached. Follow-up was completed in all patients.

Statistical Analysis

Continuous variables are described as means $\pm$ SD and dichotomous data as numbers and percentages. Continuous data were compared using ANOVA for trend and categorical data using the linear by linear association. The prognostic value of LV dysfunction toward 30-day and long-term follow-up was evaluated with logistic and Cox regression analysis, respectively. Multivariate analysis was primarily adjusted for covariates (age and sex, ischemic heart disease, cerebrovascular disease, renal dysfunction, diabetes mellitus, hypertension, hypercholesterolemia, chronic obstructive pulmonary disease, and smoking status) prospectively locked into the model based on the clinical knowledge and belief that these factors might (1) contribute to the study outcomes and (2) confound the association between the primary echo predictors and the study outcomes. Secondary adjustments were done in a step-wise fashion, and these analyses were adjusted for medication use (β-blockers, statins, aspirin, oral anticoagulants, angiotensin-converting enzyme inhibitors, angiotensin-receptor blockers, diuretics, and nitrates) on top of the covariates used in the primary regression model. We report (crude and adjusted) odds and hazard ratios with their 95% confidence interval (95% CI). For all tests, a P value less than 0.05 (two sided) was considered significant. Cumulative long-term survival was determined by the Kaplan–Meier method. All analyses were performed using SPSS version 15.0 statistical software (SPSS, Inc., Chicago, IL).

Results

Patient Population

A total of 1,005 patients undergoing open vascular (n = 649 or 65%) or endovascular (n = 356 or 35%) surgery were included in the study. Of the open vascular surgery patients, 148 patients (23%) underwent carotid artery repair, 249 patients (38%) underwent abdominal aorta repair, and 252 patients (39%) underwent lower extremity artery repair. In comparison, of the endovascular patients, 90 patients (25%) underwent carotid artery repair, 162 patients (46%) underwent abdominal aorta repair, and 104 patients (29%) underwent lower extremity artery repair. All patients undergoing open vascular surgery had general anesthesia, and 56 (35%) of the patients undergoing endovascular aortic repair had general anesthesia. General anesthesia was not provided for the percutaneous procedures.

The majority of patients were men (77%), and the mean age was 67 $\pm$ 10 yr. Mean follow-up was 2.2 $\pm$ 1.8 yr (range 3–79 months). Left ventricular dysfunction was diagnosed in 506 (50%) patients. Of the patients with LV dysfunction, 403 (80%) patients had asymptomatic LV dysfunction and 103 (20%) had symptomatic heart failure. Of the patients with asymptomatic LV dysfunction, 209 (52%) had asymptomatic isolated diastolic LV dysfunction and 194 (48%) had asymptomatic systolic LV dysfunction. Of the 103 patients with symptomatic heart

Table 1. Baseline Characteristics According to Left Ventricular (LV) Function

	Normal LV Function (n = 499)	Asymptomatic Isolated Diastolic LV Dysfunction (n = 209)	Asymptomatic Systolic LV Dysfunction (n = 194)	Symptomatic Heart Failure (n = 103)	*P* Value for Trend
Demographics					
Age, mean (SD)	65 (11)	70 (10)	70 (8)	70 (10)	< 0.001
Male (%)	363 (73)	154 (74)	168 (87)	84 (82)	0.001
Systolic blood pressure, mean (SD)	141 (24)	142 (24)	141 (26)	135 (23)	0.111
Diastolic blood pressure, mean (SD)	79 (12)	80 (12)	79 (12)	77 (12)	0.199
Heart rate, mean (SD)	70 (13)	73 (13)	73 (15)	72 (15)	0.012
Medical history (%)					
Ischemic heart disease	165 (33)	83 (40)	102 (53)	80 (78)	< 0.001
Cerebrovascular disease	169 (34)	83 (40)	76 (39)	25 (24)	0.603
Renal dysfunction	62 (12)	34 (16)	41 (21)	42 (41)	< 0.001
Diabetes mellitus	141 (28)	62 (30)	64 (33)	30 (29)	0.698
Hypertension	294 (59)	153 (73)	135 (70)	76 (74)	< 0.001
Hypercholesterolemia	303 (65)	131 (65)	114 (60)	61 (63)	0.729
Chronic obstructive pulmonary disease	100 (20)	49 (23)	50 (26)	32 (31)	< 0.001
Smoker, current	225 (45)	85 (41)	69 (36)	41 (40)	0.046
Surgery type (%)					
Open	320 (64)	129 (62)	118 (61)	82 (80)	0.102
Lower extremity revascularization	131 (26)	42 (21)	43 (22)	36 (35)	0.926
Abdominal aorta repair	110 (22)	51 (24)	48 (25)	40 (39)	0.100
Carotid artery repair	79 (16)	36 (17)	27 (14)	6 (6)	0.062
Endovascular	179 (36)	80 (38)	76 (39)	21 (20)	0.102
Lower extremity revascularization	61 (12)	22 (10)	16 (8)	5 (5)	0.179
Abdominal aorta repair	71 (14)	40 (19)	37 (19)	14 (14)	0.065
Carotid artery repair	47 (10)	18 (9)	23 (12)	2 (1)	0.633
Medication (%)					
β-blockers	368 (74)	161 (77)	162 (84)	87 (84)	0.001
Statins	352 (71)	145 (70)	149 (77)	72 (70)	0.433
Aspirin	303 (61)	110 (53)	114 (60)	61 (59)	0.578
Oral anticoagulants	61 (12)	35 (17)	41 (21)	27 (26)	< 0.001
Angiotensin-converting enzyme inhibitors	129 (26)	65 (31)	63 (33)	53 (52)	< 0.001
Angiotensin receptor blockers	49 (13)	29 (14)	36 (19)	23 (22)	0.011
Diuretics	95 (19)	54 (26)	56 (29)	49 (48)	< 0.001
Nitrates	32 (6)	19 (9)	20 (10)	30 (29)	< 0.001

failure, 72 (70%) patients had New York Heart Association Class II, 28 (27%) patients had New York Heart Association Class III (12 patients had signs of fluid retention objectified as peripheral edema), and 3 (3%) patients had New York Heart Association Class IV, with signs of pulmonary edema objectified with physical examination.

Baseline Characteristics

Clinical parameters are shown in table 1. Patients with LV dysfunction were older and had higher incidence of ischemic heart disease, renal dysfunction, hypertension, chronic obstructive pulmonary disease and had higher resting heart rate compared with patients with normal LV function. In addition, patients with LV dysfunction more often received β-blockers, oral anticoagulants, angiotensin-converting enzyme inhibitors, angiotensin-receptor blockers, diuretics, and nitrates. Patients with asymptomatic systolic LV dysfunction or symptomatic heart failure were more often men. A higher number of patients with symptomatic heart failure underwent open surgery compared with the other groups.

30-day Outcome

During 30-day follow-up, 172 (17%) patients had a nonfatal myocardial event of which 131 (76%) patients had myocardial ischemia and 41 (24%) patients had myocardial infarction. In total, 51 (10%) patients with normal LV function had a 30-day CV event, compared with 38 (18%) patients with asymptomatic isolated diastolic LV dysfunction, 44 (23%) patients with asymptomatic systolic LV dysfunction and 50 (49%) patients with symptomatic heart failure ($P < 0.001$, table 2). Multivariate analyses, in patients undergoing open surgery, demonstrated that asymptomatic isolated diastolic LV dysfunction, asymptomatic systolic LV dysfunction, and symptomatic heart failure were all associated with 30-day CV events with odds ratio of 1.8 (95% CI 1.1–2.9), 2.3 (95% CI 1.4–3.6), and 6.8 (95% CI 4.0–11.6), respectively (table 3). Other risk factors associated with 30-day CV events were age, ischemic heart disease, renal dysfunction, and chronic obstructive pulmonary disease with odds ratios of 1.8 (95% CI 1.0–1.1), 1.7 (95% CI 1.1–2.6), 3.9 (95% CI 2.2–7.1), and 1.8 (95% CI 1.2–2.6), respectively. Mul-

Table 2. Left Ventricular (LV) Function and Postoperative Outcome

	Normal LV Function	Asymptomatic Isolated Diastolic LV Dysfunction	Asymptomatic Systolic LV Dysfunction	Symptomatic Heart Failure	*P* Value
30-day					
Cardiovascular events (183)	51/499 (10)	38/209 (18)	44/194 (23)	50/103 (49)	< 0.001
Myocardial ischemia/infarction (172)	50/499 (10)	36/209 (17)	41/194 (21)	45/103 (44)	< 0.001
Cardiovascular mortality (24)	2/499 (0)	4/209 (2)	7/194 (4)	11/103 (11)	< 0.001
All cause mortality (29)	6/499 (1)	5/209 (2)	7/194 (4)	11/103 (11)	< 0.001
Long term					
Cardiovascular mortality (107)	15/499 (3)	21/209 (10)	31/194 (16)	40/103 (39)	< 0.001
All-cause mortality (164)	54/499 (11)	31/209 (15)	38/194 (20)	41/103 (40)	< 0.001

All values are given as n (%).

tivariate analyses, in patients undergoing endovascular surgery, demonstrated that symptomatic heart failure was associated with 30-day CV events with an odds ratio of 9.3 (95% CI 2.3–37.7; table 4). For both types of surgical procedures, additional adjustment for medication use (β-blockers, statins, angiotensin-converting enzyme inhibitors, angiotensin-receptor blockers, and diuretics) did not change the prognostic value of LV dysfunction toward 30-day outcome.

Long-term Outcome

During long-term follow-up, 164 (16%) patients died. The study endpoint long-term CV mortality was reached in 107 (11%) patients. In total, 15 (3%) patients with normal LV function died due to CV events, compared with 21 (10%) patients with asymptomatic isolated diastolic LV dysfunction, 31 (16%) patients with asymptomatic systolic LV dysfunction, and 40 (39%) patients with symptomatic heart failure ($P < 0.001$, table 2). Cumulative survival for all patients is shown in figure 1 (log rank, $P < 0.001$). Of the patients with LV dysfunction who reached the study endpoint long-term CV mortality, 48 patients (52%) demonstrated myocardial ischemia or infarction during 30-day follow-up. Multivariate analyses, in patients undergoing open surgery, demonstrated that asymptomatic isolated diastolic LV dysfunction, asymptomatic systolic LV dysfunction, and symptomatic heart failure were all associated with long-term CV mortality with hazard ratios of 3.0 (95% CI 1.5–6.0), 4.6 (95% CI 2.4–8.5), and 10.3 (95% CI 5.4–19.3), respectively (table 3). Other risk factors associated with long-term CV mortality were age, ischemic heart disease, renal dysfunction, and smoking with hazard ratios of 1.1 (95% CI 1.1–1.2), 1.6 (95% CI 1.1–2.8), 2.5 (95% CI 1.3–5.1), and 2.0 (95% CI 1.2–3.1), respectively. Multivariate analyses, in patients undergoing endovascular surgery, demonstrated that symptomatic heart failure was associated with long-term CV mortality with a hazard ratio of 11.4 (95% CI 3.7–35.6; table 4). For both types of surgical procedures, additional adjustment for medication use did not change the prognostic value of LV dysfunction toward long-term outcome.

Table 3. Association between Left Ventricular (LV) Function and Postoperative Outcome: Open Vascular Surgery

		Odds Ratio (95% CI)	
	n (%)	Univariate	Multivariate
30-day cardiovascular events			
Normal LV function	44/320 (14)	1.0	1.0
Asymptomatic isolated diastolic LV dysfunction	30/129 (23)	2.0 (1.2–3.1)	1.8 (1.1–2.9)
Asymptomatic systolic LV dysfunction	36/118 (31)	2.6 (1.7–4.0)	2.3 (1.4–3.6)
Symptomatic heart failure	44/82 (54)	8.3 (5.1–13.4)	6.8 (4.0–11.6)
Long-term cardiovascular mortality		Hazard ratio (95% CI)	
Normal LV function	8/320 (3)	1.0	1.0
Asymptomatic isolated diastolic LV dysfunction	14/129 (11)	3.5 (1.8–6.8)	3.0 (1.5–6.0)
Asymptomatic systolic LV dysfunction	23/118 (20)	5.2 (2.8–9.7)	4.6 (2.4–8.5)
Symptomatic heart failure	31/82 (38)	13.6 (7.5–24.6)	10.3 (5.4–19.3)
Long-term all-cause mortality			
Normal LV function	37/320 (12)	1.0	1.0
Asymptomatic isolated diastolic LV dysfunction	20/129 (16)	1.5 (0.9–2.3)	1.4 (0.9–2.1)
Asymptomatic systolic LV dysfunction	28/118 (24)	1.8 (1.2–2.7)	1.7 (1.1–2.5)
Symptomatic heart failure	32/82 (39)	3.9 (2.6–5.8)	3.1 (2.0–4.8)

Multivariate analysis adjusted for age, gender, ischemic heart disease, cerebrovascular disease, renal dysfunction, diabetes mellitus, hypertension, hypercholesterolemia, chronic obstructive pulmonary disease, and smoking.

CI = confidence interval.

Table 4. Association between Left Ventricular (LV) Function and 30-day and Long-term Outcome: Endovascular Surgery

		Odds Ratio (95% CI)	
	n (%)	Univariate	Multivariate
30-day cardiovascular events			
Normal LV function	7/179 (4)	1.0	1.0
Asymptomatic isolated diastolic LV dysfunction	8/80 (10)	2.7 (0.9–7.8)	2.2 (0.7–6.9)
Asymptomatic systolic LV dysfunction	8/76 (11)	2.9 (1.0–8.6)	2.5 (0.8–7.8)
Symptomatic heart failure	6/21 (29)	9.8 (2.9–33.0)	9.3 (2.3–37.7)
Long-term cardiovascular mortality		Hazard ratio (95% CI)	
Normal LV function	7/179 (4)	1.0	1.0
Asymptomatic isolated diastolic LV dysfunction	7/80 (9)	2.2 (0.8–6.4)	1.7 (0.5–5.3)
Asymptomatic systolic LV dysfunction	8/76 (11)	2.4 (0.8–6.5)	2.2 (0.8–6.6)
Symptomatic heart failure	9/21 (43)	14.5 (5.4–39.1)	11.4 (3.7–35.6)
Long-term all-cause mortality			
Normal LV function	17/179 (10)	1.0	1.0
Asymptomatic isolated diastolic LV dysfunction	11/80 (14)	1.5 (0.7–3.2)	1.2 (0.5–2.7)
Asymptomatic systolic LV dysfunction	10/76 (13)	1.3 (0.6–2.9)	1.2 (0.5–2.9)
Symptomatic heart failure	9/21 (43)	6.1 (2.7–13.8)	5.1 (1.9–13.3)

Multivariate analysis adjusted for age, gender, ischemic heart disease, cerebrovascular disease, renal dysfunction, diabetes mellitus, hypertension, hypercholesterolemia, chronic obstructive pulmonary disease, and smoking.

CI = confidence interval.

Discussion

This study demonstrated that open vascular surgery patients with asymptomatic isolated diastolic or systolic LV dysfunction were at increased risk for 30-day CV events and long-term CV mortality. In endovascular surgery patients, only symptomatic heart failure was associated with an increased risk for 30-day CV events and long-term CV mortality. In the American College of Cardiology/American Heart Association and European Society of Cardiology perioperative guidelines, symptoms of heart failure are acknowledged to be an important predictor of postoperative outcome. However, our data suggest that asymptomatic LV dysfunction should be imbedded in preoperative risk stratification of vascular surgery patients as well.

Left ventricular dysfunction is caused by neurohormonal responses activated by cardiac injury or an increased hemodynamic load. These responses are known to induce (1) sympathetic stimulation, (2) salt and water retention, and (3) vasoconstriction.[19,20] Although these responses are initially adaptive, they become maladaptive over time because of a process called LV remodeling. This process leads to (1) LV hypertrophy (concentric remodeling) associated with diastolic LV dysfunction or (2) LV dilatation (eccentric remodeling) associated with systolic LV dysfunction.[21] During surgery, high catecholamine production is responsible for vasoconstriction and hemodynamic stress.[2] Surgical stress and perioperative fluid administration increases ventricular pre- and afterload, making patients with systolic LV dysfunction susceptible for perioperative myocardial damage.[22] During surgery, there is an increased oxygen demand, and patients with coronary artery stenosis are at an increased risk for perioperative myocardial damage because of an oxygen supply–demand mismatch.[3,23] Patients with diastolic LV dysfunction have a reduced coronary flow reserve, making them susceptible to perioperative myocardial damage as well.[21] In addition, concentric remodeling causes a reduction in LV compliance, making LV filling dependent on blood volume contributed by ventricular preload. Perioperative LV preload reductions can result in tachycardia with concomitant reduction in coronary perfusion, leading to myocardial damage.[24]

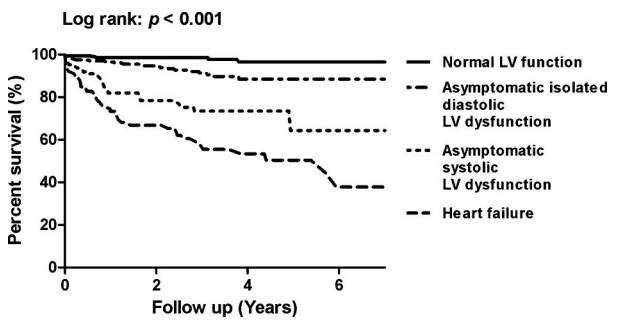

Fig. 1. Left ventricular (LV) function and long-term survival after vascular surgery.

Episodes of perioperative myocardial damage are most often silent, and therefore patients often remain untreated, which might contribute to an increased risk of long-term CV mortality.[25,26] We have found that approximately three of four patients with perioperative damage had LV dysfunction. In line with previous studies, we have found that endovascular surgery was associated with a reduced incidence of perioperative myocardial damage, compared with open surgery, possibly explained by reduced myocardial stress and the need for lower fluid administration during endovascular procedures.[27,28] In addition, one should keep in mind that carotid surgery is associated with lower cardiac risk compared with abdominal aneurysm repair and lower extremity revascularization.

Myocardial perfusion scintigraphy and pharmacologic stress echocardiography are known to stratify patients at risk for perioperative myocardial damage[29–31] accurately. In addition, the presence of wall motion abnormalities at rest has predictive value for the development of perioperative cardiac events as well.[31] Until now, studies addressing the impact of heart failure in surgical patients mainly focused on symptomatic patients with a reduced LV ejection fraction.[5,23,32,33] A retrospective study conducted by Xu-Cai *et al.* evaluated the impact of symptomatic heart failure with a preserved LV ejection fraction, demonstrating an increased risk for long-term mortality. However, no increased risk for perioperative mortality was observed.[34] Recently, Matyal *et al.*[35] studied 313 vascular surgery patients and found diastolic LV dysfunction to be a predictor of adverse CV outcome; however, systolic LV dysfunction was not. Several differences between the study conducted by Matyal *et al.* and this study, which might explain the different outcomes regarding the effect of systolic LV dysfunction on CV outcome, are as follows: (1) subanalysing open *versus* endovascular surgery, (2) troponin T measurements obtained routinely or when clinically indicated, (3) definition of the LV function groups, and (4) follow-up duration. To our knowledge, this study is first to demonstrate that asymptomatic LV dysfunction (diastolic and systolic) is associated with an increased risk for open vascular surgery patients.

In the most recent American College of Cardiology/American Heart Association and European Society of Cardiology perioperative guidelines,[3,9] the prognostic value of symptoms of heart failure on postoperative outcome is well acknowledged and incorporated in the decision process with regard to proceeding directly to surgery. In addition, preoperative cardiac risk indices incorporate symptomatic heart failure as an important risk factor.[4,6,36] To define surgical patients at "high risk" for developing adverse CV events, one point should be assigned to patients with (a medical history of) current symptoms of heart failure, next to other risk factors such as ischemic heart disease, cerebrovascular disease, renal dysfunction, diabetes mellitus, or high-risk surgery. To prevent an underestimation of the "cardiac risk burden" of vascular surgery patients, our data suggest that asymptomatic LV dysfunction should be imbedded in these risk indices as well.

Our results indicate that asymptomatic LV dysfunction is not associated with increased risk for 30-day CV events and long-term CV mortality in endovascular surgery patients. An explanation of this finding could lie in the fact that endovascular surgery is associated with reduced myocardial stress compared with open vascular surgery.[27,28] Therefore, the detection of asymptomatic LV dysfunction with routine preoperative echocardiography could add valuable information in the decision between open and endovascular surgery.

Biochemical markers, such as N-terminal pro-B-type natriuretic peptide, are increasingly used in the detection and exclusion of heart failure[37] and have been proven to predict poor outcome after vascular surgery.[38] Standard measurements of this biochemical marker may play an important role in detecting asymptomatic LV dysfunction in vascular surgery patients, regardless of the presence of heart failure symptoms. However, the diagnostic value of natriuretic peptides in asymptomatic patients at risk for diastolic or systolic LV dysfunction is controversial. In a recent study conducted by Luers *et al.*,[39] plasma levels of natriuretic peptides significantly increased with a decreasing ejection fraction and with a severe degree of diastolic dysfunction. Therefore, the authors suggest that high-risk individuals may be screened most efficiently by using a score system, incorporating clinical data and N-terminal pro-B-type natriuretic peptide. In vascular surgery patients, future studies are needed to evaluate the value of B-type natriuretic peptides *versus* echocardiography to detect LV dysfunction in patients with or without heart failure symptoms. In 2003, Grayburn and Hillis[40] proposed to shift the paradigm from preoperative noninvasive risk stratification to therapy. Routine preoperative evaluation of LV function could reveal patients with asymptomatic LV dysfunction eligible for pharmacologic treatment. Before surgery, low-dose β-blockade could be considered and titrated to obtain a heart rate between 60 and 70 beats/min.[41] In addition, initiation of angiotensin blockers could be considered after surgery.[42]

Potential limitations of these data merit consideration. First, the study population consisted of patients referred to a tertiary referral center and may not fully represent the general vascular surgery population scheduled. Second, although two experienced investigators performed an offline assessment of ultrasound images, we cannot rule out interobserver variability to have had a minor influence on our results. Third, the evaluation of diastolic LV function with conventional Doppler, ratio of mitral peak velocity of early filling (E) to mitral peak velocity of late filling (A), and pulmonary vein filling patterns was limited due to preload dependency and not including Valsalva maneuver, ratio of mitral peak velocity of early filling (E) to early diastolic mitral annular velocity (E′), isovolumetric relaxation time, or tissue Doppler imaging.

In conclusion, this study demonstrated that asymptomatic LV dysfunction is a predictor of CV outcome in open vascular surgery patients. These data suggest that preoperative risk stratification should not solely include symptomatic heart failure, already acknowledged in the American College of Cardiology/American Heart Association and European Society of Cardiology perioperative guidelines; however, asymptomatic LV dysfunction should be imbedded as well. Standard preoperative evaluation of LV function could be argued based on our results, suggesting a move toward more routine use of cardiac echo in open vascular surgery patients.

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