

# Left Ventricular Assessment in Myocardial Infarction

## The VALIANT Registry

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**Background:** How often echocardiography and cardiac catheterization are used to evaluate left ventricular (LV) function in patients with myocardial infarction (MI) and how they are associated with quality of care is unknown.

**Methods:** Patients with MI in the Valsartan in Acute Myocardial Infarction (VALIANT) registry were divided into those with (n=1423) and without (n=3968) heart failure (HF), and the use of either echocardiography or cardiac catheterization for LV assessment in each group was compared along with associated baseline characteristics. We evaluated the association between LV assessment and discharge medications. Using a multivariable model with a propensity analysis, we evaluated the association of LV assessment with in-hospital outcomes.

**Results:** Of the patients with HF, 322 (22.6%) had no LV assessment. Patients with HF with LV assessment were discharged more frequently under treatment with aspirin (81.3% vs 70.0%;  $P<.001$ ),  $\beta$ -blockers (65.6% vs

56.4%;  $P=.008$ ), clopidogrel (30.4% vs 14.0%;  $P<.001$ ), and statins (45.9% vs 34.2%;  $P<.001$ ). Patients without HF who underwent LV assessment were discharged more frequently under treatment with an angiotensin-converting enzyme inhibitor (53.8% vs 41.5%;  $P<.001$ ). After adjustment for regional use, other covariates, and revascularization, LV assessment was associated with lower in-hospital mortality in patients with HF (adjusted odds ratio [OR], 0.45;  $P<.001$ ) and in patients without HF (adjusted OR, 0.30;  $P<.001$ ). After excluding deaths during the first 2 days, LV assessment remained associated with lower mortality in patients with HF (adjusted OR, 0.59;  $P=.03$ ) and in patients without HF (adjusted OR, 0.41;  $P<.001$ ).

**Conclusion:** Left ventricular assessment was frequently not performed during the in-hospital stay of patients with acute MI, including those with clinical HF, and its use was associated with better quality of care.

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**C**URRENT GUIDELINES FROM professional organizations emphasize early identification and treatment of patients with acute myocardial infarction (MI) or acute coronary syndromes with high-risk features.<sup>1-3</sup> Among the most important predictors of 30-day mortality in patients with MI is evidence of either heart failure (HF) by Killip classification or left ventricular (LV) systolic dysfunction.<sup>4-6</sup> Thus, evidence of HF or LV systolic dysfunction can influence the choice of therapy.<sup>7</sup> In addition, as state and federal efforts to measure quality and publicly report outcomes expand, professional organizations have developed performance measures of quality of care. One such measure is LV assessment in patients with HF who have a clinical event.<sup>8-10</sup> For patients with MI who develop complications such as HF or evidence of LV systolic dysfunction, current guidelines recommend further evalu-

ation, yet it is not known how often echocardiography or cardiac catheterization is used to evaluate hospitalized patients with MI, including those complicated by HF.<sup>1-3</sup>

Numerous studies have evaluated the use of cardiac catheterization in MI, but little is known about the association of LV assessment by either echocardiography or cardiac catheterization with benchmarks of quality care.<sup>11-14</sup> In high-risk patients with MI, such as those with HF, diagnostic testing has been recommended to guide revascularization and/or medical therapy.<sup>1,2</sup> Cardiac catheterization plays a pivotal role in evaluation, but many hospitals do not have invasive cardiovascular facilities, and entire regions have limited access to this technology. Therefore, noninvasive risk stratification often guides the intensity of care and helps determine the need and urgency of triage for invasive procedures. However, the use of noninvasive diagnostic testing such as echocardiography in the acute MI setting has not been well described.

Using data collected from patients with MI enrolled in the registry associated with the Valsartan in Acute Myocardial Infarction (VALIANT) trial, we examined the frequency of LV assessment by echocardiography or cardiac catheterization, its association with quality of care such as guideline-recommended therapies, and outcomes.<sup>15,16</sup>

## METHODS

### STUDY DESIGN

The VALIANT registry was an ancillary study to the main VALIANT trial. The design of VALIANT has been reported previously.<sup>16</sup> Briefly, VALIANT was designed to evaluate whether the angiotensin II receptor blocker valsartan, alone or combined with the angiotensin-converting enzyme (ACE) inhibitor captopril, reduces mortality compared with captopril alone in patients with MI complicated by HF and/or LV systolic dysfunction. The VALIANT registry was designed to capture information about the general VALIANT MI population and about international differences in patients with MI and treatments. During a specified portion of the VALIANT trial randomization period, sites were asked to enter all patients presenting with the clinical diagnosis of MI into a consecutive screening registry. The registry form collected the medical history, medication use before MI presentation, initial electrocardiogram results, medication use during the initial day of MI diagnosis, in-hospital clinical events, and discharge disposition. The form also collected procedures performed before discharge, including echocardiography and cardiac catheterization.

### STUDY POPULATION

All patients admitted during specified screening periods with a clinical diagnosis of MI as determined by the treating physician were entered into the VALIANT registry. Sites chose between limited registry participation for either 2 weeks or 6 months. Although not required for registry enrollment, sites were instructed to use as a guide the VALIANT trial MI inclusion criteria of biomarker evidence of myocardial necrosis and either a symptom complex or an electrocardiogram consistent with MI.<sup>16,17</sup>

Investigators were asked to designate HF status based on Killip classification (none, I; pulmonary rales, II; pulmonary edema, III; and cardiogenic shock, IV). Clinical events that occurred at presentation or during hospital stay, including worsening HF (defined as unplanned intravenous treatment of new or preexisting HF with inotropic agents, diuretics, or vasodilators) and cardiogenic shock, were also recorded. For this study, patients with HF are defined as those with Killip class of II or higher on presentation or development of HF after admission (defined as unplanned intravenous treatment of HF with inotropic agents, diuretics, or vasodilators).

### STATISTICAL ANALYSIS

All primary patient data were collected as part of the VALIANT registry. Continuous baseline characteristics and clinical outcomes were reported as medians with interquartile ranges. Categorical factors were reported using frequencies and percentages. Comparisons of baseline characteristics, variables at presentation, medications (within 24 hours and at discharge), procedures, and clinical event rates were analyzed by using Pearson  $\chi^2$  tests for categorical variables and Wilcoxon rank-sum tests for ordinal and continuous measures. For percentage calculations, the missing values were assumed to be zero.

Because patients who undergo echocardiography or cardiac catheterization may do so because of different factors, potential confounding was adjusted for by developing a propensity score for having either an echocardiogram or cardiac catheterization.<sup>18-20</sup> The propensity score was defined as the conditional probability of getting an echocardiogram or cardiac catheterization given the observed covariates. To calculate the propensity score, possible predictors of receiving an echocardiogram or cardiac catheterization were chosen based on a previously published mortality model from the VALIANT registry.<sup>15</sup> The model was selected using the following baseline and presentation variables: age, sex, weight, race, history of angina, prior MI, prior percutaneous coronary intervention, prior bypass surgery, prior HF, stroke, peripheral vascular disease, dyslipidemia, chronic obstructive pulmonary disease, renal insufficiency, hypertension, diabetes, current smoking, first recorded blood pressures, heart rate, Killip class, ST-segment category (elevation, depression, nonspecific changes, Q waves in infarct zone, and left bundle branch block), and MI location (anterior vs inferior). Inclusion into the final model was based on stepwise selection with an  $\alpha$  level of  $\leq .05$ . From this model, predicted values were obtained, ranked from lowest to highest probability, and then grouped into quintiles of likelihood for having either an echocardiogram or cardiac catheterization. Thus, the first quintile included patients who had the lowest likelihood of receiving an echocardiogram or cardiac catheterization, and the fifth included those with the highest likelihood of receiving the test. If the propensity score performed well at stratifying patients into those likely to undergo LV assessment, then we assumed that the score adequately adjusted for imbalances. Thus, each baseline characteristic would be equally distributed within each quintile (or strata). Finally, a complete model without stepwise selection was tested to determine if any residual confounding from available data was present.

In-hospital mortality was modeled using the variable for test (echocardiography or cardiac catheterization) use alone. This gave an estimate of the association between the test procedure and outcome before any adjustments for imbalances were made. A second model was then created that included not only the test procedure but also the strata for propensity to receive a test procedure and revascularization with either percutaneous coronary intervention or coronary artery bypass grafting. The statistical evaluation of the test procedure in this model estimated the effect after accounting for potential confounding.

For all analyses, a 2-tailed *P* value of  $< .05$  was considered statistically significant. All analyses were performed using SAS statistical software (SAS Institute, Cary, NC).

## RESULTS

Between November 1999 and June 2001, 5573 consecutive patients with MI were enrolled in the VALIANT registry at 84 hospitals in 9 countries (**Table 1**). Of the patients in the registry, 2479 (44.5%) underwent echocardiography, 3418 (61.3%) underwent cardiac catheterization, and 1423 (25.5%) had HF. Of those with HF, 346 (24.3%) developed HF after presentation. Of those entered into the registry, 182 were missing Killip class data and were excluded from the analysis.

### BASELINE ASSESSMENT

Baseline characteristics associated with greater likelihood of undergoing LV assessment by either echocardi-

**Table 1. VALIANT Registry Enrollment**

Country	Sites, No.	Patients, No.	Patients Who Underwent Echo or Cath, %	Patients Who Underwent Echo, %	Patients Who Underwent Cath, %
Argentina	10	247	89.4	70.8	44.1
Australia	18	423	45.8	36.2	14.6
Canada	5	1148	87.7	43.1	77.0
Czech Republic	2	133	85.7	49.6	70.9
Germany	2	68	97.1	94.1	75.0
Italy	2	27	100	100	7.4
The Netherlands	3	369	75.3	68.6	19.8
New Zealand	5	147	58.5	57.1	25.8
United States	37	3011	86.4	38.6	73.6

Abbreviations: Cath, cardiac catheterization; Echo, echocardiography; VALIANT, Valsartan in Acute Myocardial Infarction.

**Table 2. Procedure Use Characteristics of Patients With MI Complicated by HF\***

Characteristic	Echo or Cath (n = 1101)	Neither (n = 322)	P Value
Age, y	73.1 (62.7-80.1)	79.0 (70.3-84.7)	<.001
Male	657 (59.7)	153 (47.5)	<.001
Race			
Black	46 (4.2)	11 (3.4)	.76
White	1013 (92.0)	300 (93.2)	
Other	35 (3.2)	8 (2.5)	
Weight, kg	79.0 (66.0-90.0)	70.0 (60.0-82.0)	<.001
Blood Pressure, mm Hg			
Systolic	131.0 (112.0-152.0)	135.0 (112.0-158.0)	.58
Diastolic	75.5 (62.5-90.0)	75.0 (63.0-90.0)	.62
Heart rate, beats/min	88.0 (72.0-105.0)	90.0 (74.0-108.0)	.23
Angina	253 (23.0)	95 (29.5)	.02
Prior MI	321 (29.2)	136 (42.4)	<.001
Prior PCI	142 (12.9)	30 (9.3)	.08
Prior bypass surgery	139 (12.6)	44 (13.7)	.62
Prior HF	236 (21.4)	93 (28.9)	.005
Prior stroke	155 (14.1)	53 (16.5)	.29
Peripheral vascular disease	166 (15.1)	252 (14.9)	.94
COPD	191 (17.4)	55 (17.1)	.91
Hypertension	645 (58.6)	162 (50.3)	.008
Diabetes mellitus	384 (34.9)	100 (31.1)	.20
Current smoker	248 (22.5)	30 (9.3)	<.001
Hyperlipidemia	394 (35.8)	80 (24.8)	<.001
Renal insufficiency	131 (11.9)	38 (11.8)	.96
Presenting ECG data, %			
ST-segment elevation ≥2 leads	42.1	29.2	<.001
ST-segment depression	32.1	34.5	.42
Anterior MI, %	37.5	36.3	.70
Inferior MI, %	26.8	18.9	.004
Left bundle branch block, %	9.2	12.7	.06

Abbreviations: Cath, cardiac catheterization; COPD, chronic obstructive pulmonary disease; ECG, electrocardiogram; Echo, echocardiography; HF, heart failure; MI, myocardial infarction; PCI, percutaneous coronary intervention.

\*Data are presented as median (25th-75th percentiles) or number (percentage), unless otherwise specified.

**Table 3. Echo and Cath Use in Patients With and Without Heart Failure\***

Procedure Used		No. (%)	
Echo	Cath	HF (n = 1423)	No HF (n = 3968)
Yes	Yes	382 (26.8)	982 (24.8)
Yes	No	422 (29.7)	607 (15.3)
No	Yes	297 (20.9)	1757 (44.3)
No	No	322 (22.6)	622 (15.7)

Abbreviations: Cath, cardiac catheterization; Echo, echocardiography; HF, heart failure.

HF vs no HF,  $P < .001$ .

ography or cardiac catheterization included younger age, male sex, hypertension, current smoker, hyperlipidemia, ST-segment elevation MI, and inferior MI location (**Table 2**).

### PROCEDURE USE

Overall, patients who had HF were more likely to undergo echocardiography and less likely to undergo cardiac catheterization compared with those without HF (**Table 3**). The converse was true for patients not clinically identified as having HF. Of those who developed worsening HF, 24.0% had neither an echocardiogram nor cardiac catheterization.

### DISCHARGE MEDICATIONS

In general, patients who underwent echocardiography or cardiac catheterization were more likely to be prescribed guideline-recommended medications (**Table 4**). Patients without HF were discharged with a prescribed ACE inhibitor more frequently if they had LV assessment with echocardiography or cardiac catheterization. Aspirin,  $\beta$ -blocker, and statin use on discharge was also more frequent in patients with or without HF if either echocardiography or cardiac catheterization was performed. Clopidogrel use was also higher in patients who underwent either procedure, but this was mostly because of cardiac catheterization.

**Table 4. Discharge Medications and Procedure Use**

Medication	No Heart Failure, %			Heart Failure, %		
	Echo or Cath (n = 3256)	Neither (n = 557)	P Value	Echo or Cath (n = 973)	Neither (n = 243)	P Value
Aspirin	88.9	79.5	<.001	81.3	70.0	<.001
ACE inhibitor	53.8	41.5	<.001	55.6	51.9	.29
Angiotensin receptor blocker	3.8	3.6	.83	4.7	5.4	.69
β-blocker	80.6	72.7	<.001	65.6	56.4	.008
Calcium blocker	14.7	16.7	.23	13.9	21.0	.006
Loop diuretic	14.3	17.6	.046	50.3	51.4	.74
Spironolactone	1.7	3.6	.002	7.6	5.8	.32
Digoxin	7.8	8.6	.49	21.5	21.8	.91
Amiodarone	4.1	3.1	.26	9.3	5.8	.08
Nitrate	24.9	30.3	.006	33.9	48.6	<.001
Clopidogrel	50.2	28.9	<.001	30.4	14.0	<.001
Coumadin	10.0	7.4	.05	15.0	10.7	.09
Statin	57.6	51.0	.004	45.9	34.2	<.001

Abbreviations: ACE, angiotensin-converting enzyme; Cath, cardiac catheterization; Echo, echocardiography.

## CLINICAL OUTCOMES

The mortality rate was 24.5% in patients who presented with HF but did not undergo either echocardiography or cardiac catheterization (**Table 5; Figure**). After adjusting for propensity score quintile, regional use, and revascularization by percutaneous coronary intervention or coronary artery bypass grafting, the use of echocardiography or cardiac catheterization was associated with lower in-hospital mortality in patients with HF (adjusted odds ratio [OR], 0.45;  $P < .001$ ) (**Table 6**). If deaths within 2 days were excluded, the mortality rate was 17.1% in patients who did not undergo either echocardiography or cardiac catheterization compared with 10.0% in those who underwent either test (adjusted OR, 0.59;  $P = .03$ ). This difference in mortality was not significant if deaths within 3 days were excluded (adjusted OR, 0.68;  $P = .15$ ) (Table 6). The overall mortality rate was lower in patients without clinical HF than in those with HF (3.9% vs 14.5%), but the association of LV assessment with lower mortality was consistent. After excluding deaths within 3 days of admission, the adjusted OR remained significant at 0.44 ( $P = .002$ ) (Table 6).

**Table 7** gives the covariates that significantly increased the propensity for undergoing echocardiography or cardiac catheterization (c index, 0.72). The most significant covariates were age, ST-segment elevation, and region. In addition, a complete model with all baseline variables including medications prior to admission and splines for systolic blood pressure and diastolic blood pressure (c index, 0.73) did not change any of the results, so the parsimonious model is presented herein to illustrate the most important factors associated with LV assessment.

## COMMENT

To our knowledge, this is the first study to characterize the use of echocardiography or cardiac catheterization for LV assessment in patients with MI in an international registry. Our results suggest that echocardiogra-

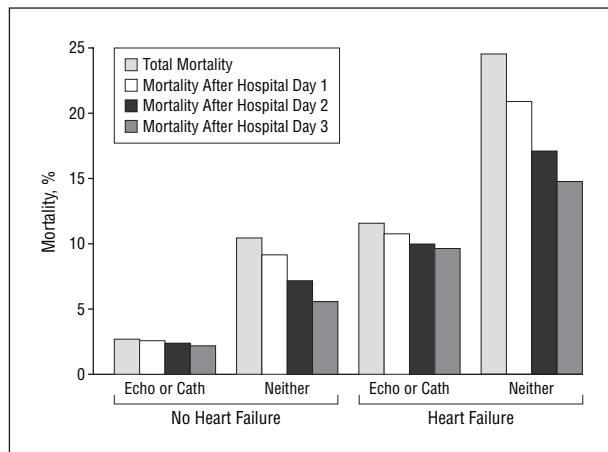
phy and cardiac catheterization are frequently not performed during the in-hospital MI period, including in patients with an MI complicated by HF. Patients who did not undergo echocardiography or cardiac catheterization were less often discharged on therapies recommended by clinical practice guidelines.

In addition, our data suggest that assessing LV function in patients with MI is associated with better outcomes, although other confounding factors cannot be fully excluded. Several possible explanations for our findings exist. Physicians who comply with guidelines in general may order echocardiograms or cardiac catheterization more often compared with those who do not comply. Thus, the overall care is better for those who comply with guidelines. Echocardiography or cardiac catheterization may provide information that favorably alters management. Either may lead to early identification of patients with LV systolic dysfunction or other evidence of impairment, increasing the use of medical therapy with proven survival benefit or encouraging more vigilant attention to a patient's clinical status. This seemed to be partly the case in patients without HF, who were prescribed ACE inhibitors more frequently if LV assessment was done. In addition, cardiac catheterization and associated revascularization have a direct impact on survival; however, even after adjustment for this, LV assessment remains associated with improved survival. Furthermore, procedure use may reflect payer status, where less expensive noninvasive tests substitute for cardiac catheterization in populations with poor insurance, a phenomenon evidenced by an analysis of the National Registry of Myocardial Infarction 2 (NRMI-2) database.<sup>12</sup> Finally, patients who die early may not have a chance to undergo LV assessment. When patients with HF who died within the first 3 days of admission were excluded, LV assessment was not statistically significantly associated with survival. Although patients who appear to be worse may undergo LV assessment more often, some probably die unexpectedly because of arrhythmias or other sudden mechanical complications without an opportunity

**Table 5. Use of Echo or Cath and Clinical Events**

Clinical Event	No Heart Failure, %			Heart Failure, %		
	Echo or Cath (n = 3346)	Neither (n = 622)	P Value	Echo or Cath (n = 1101)	Neither (n = 322)	P Value
Atrial fibrillation	7.7	9.2	.21	19.2	17.7	.56
Recurrent ischemia	9.4	8.7	.56	11.4	11.8	.86
Sustained ventricular tachycardia/fibrillation	4.6	5.0	.65	9.1	6.8	.21
Recurrent MI	1.5	1.3	.69	2.5	4.0	.16
Hypotension requiring intervention	7.6	6.9	.56	19.5	11.5	<.001
Stress test	8.8	8.2	.65	7.1	3.7	.03
Mortality	2.7	10.5	<.001	11.6	24.5	<.001

Abbreviations: Cath, cardiac catheterization; Echo, echocardiography; MI, myocardial infarction.



**Figure.** Mortality of patients with acute myocardial infarction relative to use of echocardiography (echo) or cardiac catheterization (cath).

for LV assessment. Assessing LV function early in the course of treatment of patients with MI may detect some, but not all, of these complications.

Even though HF confers a high risk for patients with MI, clinicians in the VALIANT registry performed cardiac catheterization more often in the lowest-risk patients and echocardiography more often in the higher-risk population of patients with MI complicated by HF. Thus, there may be a substitution of one procedure for the other. Physicians may choose to send patients who appear to be less likely to die in the near future for cardiac catheterization, or physicians may be risk averse in patients with complications. In addition, it is interesting that despite recognizing clinical HF, physicians chose not to perform further diagnostic testing. Although physicians may have believed that there was no additional information to be gained or may have been waiting for further decline, this may not be the optimal strategy.

### HF AFTER MI

Patients with MI complicated by HF have a poor prognosis. Many studies have focused on cardiogenic shock, which has a high mortality rate, but mild-to-moderate HF is one of the most common complications and strongest predictors of in-hospital death.<sup>15,21-23</sup> Stratifying patients with MI and intensifying therapy for those

at highest risk may improve prognosis. Cardiac catheterization is preferred given the benefits of revascularization, but if it is not possible, there are many reasons for using echocardiography. Determining the extent of systolic and diastolic dysfunction and mitral regurgitation adds prognostic information and may alter clinical management.<sup>24-27</sup>

With the advent of handheld echocardiography, post-MI imaging data will likely expand.<sup>28</sup> This may provide more information than what currently results from clinical examinations or 1-time tests. Unfortunately, it appears that a large group of patients does not undergo risk stratification to evaluate LV function or mitral regurgitation.

Although many studies focus on the impact of HF at presentation with MI, a significant number of patients develop HF after admission. Such patients have a risk of death and recurrent MI similar to that of patients with HF at presentation, and in this registry, 24% did not have any LV assessment.<sup>21,29</sup>

### LV ASSESSMENT AND QUALITY OF CARE

Applying evidence-based guidelines to improve outcomes of patients with MI is a focus of many national initiatives.<sup>30</sup> Determining what defines an important quality metric is a challenge to many. The American College of Cardiology/American Heart Association working group on acute MI has noted several principles for selecting quality performance measures.<sup>31</sup> For a performance measure to be an important quality standard it must be meaningful, reliable, valid, modifiable, and feasible. Thus, if evaluating LV function is an important quality measure as it is per HF guidelines, it should be tied to meaningful outcomes.<sup>8,9</sup> In addition to suggesting that LV assessment is associated with several quality markers, our data raise an intriguing question of whether LV assessment contributes to improved outcomes or is simply a factor associated with better quality of care given by those who comply with evidence-based therapies.

The reported use of LV assessment and evidence-based guideline-recommended therapies varies across other studies. In the Global Registry of Acute Coronary Events (GRACE), LV function was measured less than in our study, but patients with HF had a slightly higher

**Table 6. Mortality Risk and Procedure Use in Patients With MI Complicated by Heart Failure and in Those Without Heart Failure**

Deaths	No. (%)		Adjusted Odds Ratio (95% CI)*	P Value
	Echo or Cath (n = 1101)	Neither (n = 322)		
<b>Patients With MI Complicated by Heart Failure</b>				
Total	128 (11.6)	79 (24.5)	0.45 (0.29-0.68)	<.001
After day 1	119 (10.8)	63 (20.9)	0.53 (0.34-0.83)	.005
After day 2	108 (10.0)	50 (17.1)	0.59 (0.37-0.95)	.03
After day 3	104 (9.7)	42 (14.8)	0.68 (0.41-1.14)	.15
<b>Patients With MI Without Heart Failure</b>				
Total	90 (2.7)	65 (10.5)	0.30 (0.20-0.45)	<.001
After day 1	87 (2.6)	56 (9.0)	0.34 (0.22-0.51)	<.001
After day 2	81 (2.4)	43 (6.9)	0.41 (0.255-0.65)	<.001
After day 3	73 (2.2)	33 (5.3)	0.44 (0.26-0.74)	.002

Abbreviations: Cath, cardiac catheterization; CI, confidence interval; Echo, echocardiography; MI, myocardial infarction.

\*Odds ratios adjusted for propensity quintile for echo, percutaneous transluminal coronary angioplasty, coronary artery bypass grafting, and regional differences.

**Table 7. Covariates Associated With Undergoing Echo or Cath Before and After Propensity Score Stratification\***

Covariate	No. (%)		F Statistic	
	Echo or Cath (n = 4595)	Neither (n = 978)	Before Stratification†	After Stratification‡
Region				
Europe§	485 (10.55)	112 (11.4)	61.74 (<.001)	4.12 (.045)
Argentina	221 (4.8)	26 (2.6)		
Australia and New Zealand	280 (6.1)	290 (29.6)		
Canada	1007 (21.9)	141 (14.4)		
United States	2602 (56.6)	409 (41.8)		
Male sex	3140 (68.3)	577 (59)	31.82 (<.001)	0.36 (.55)
History of angina	794 (17.28)	221 (22.6)	15.34 (<.001)	0.15 (.70)
Previous MI	1020 (22.2)	314 (32.1)	43.81 (<.001)	0.04 (.85)
Heart failure	403 (8.7)	144 (14.7)	32.47 (<.001)	2.38 (.12)
Hypertension	2380 (51.8)	456 (46.6)	8.63 (.003)	0.01 (.90)
Current smoker	1409 (30.6)	164 (16.7)	8.63 (.003)	0.15 (.70)
Dyslipidemia	1679 (36.5)	286 (29.2)	18.86 (<.001)	0.15 (.70)
ST-segment elevation ≥2 leads	2366 (51.5)	362 (37)	68.43 (<.001)	0.17 (.68)
Inferior location	1719 (37.4)	268 (27.4)	35.41 (<.001)	1.89 (.17)
Left bundle branch block	201 (4.4)	74 (7.6)	17.56 (<.001)	0.17 (.68)
Age, y	64.2 (15.1)	69.5 (16.2)	97.63 (<.001)	0.17 (.68)
Weight, kg	84.2 (46.3)	77.1 (19.8)	17.64 (<.001)	2.8 (.09)

Abbreviations: Cath, cardiac catheterization; Echo, echocardiography; MI, myocardial infarction.

\*Data are presented as No. (%), mean (SD), or F statistic (P value). c Index = 0.72

†F statistic = square of 2-sample t statistic (P value).

‡F statistic after adjusting for propensity score quintile.

§Europe includes the Netherlands, Germany, Italy, and the Czech Republic.

rate of measurement compared with patients without HF (71.3% vs 69.0%;  $P = .04$ ).<sup>23</sup> Thus, other data besides ours show that the rate of LV assessment seems to be suboptimal, especially when considering that any patient with HF with a new clinical event should be considered for LV function reevaluation.<sup>8</sup> Post-MI echocardiography has been associated with higher rates of ACE inhibitor use. In the NRMI-2 study, an ACE inhibitor was prescribed to 59% of patients who underwent echocardiography, compared with 45% of patients who did not; the difference persisted after controlling for LV ejection fraction, anterior MI, hypertension, and congestive HF.<sup>32</sup> In the

present study, LV assessment by either echocardiography or cardiac catheterization was associated with higher use of aspirin,  $\beta$ -blockers, and statins in patients with HF. In patients without HF, ACE inhibitors were more frequently used if either echocardiography or cardiac catheterization was performed. Left ventricular assessment may provide information that influences medication use in high-risk post-MI patients. The use of beneficial therapies such as ACE inhibitors and  $\beta$ -blockers in high-risk patients continues to fall below the minimum standard, and newer strategies are needed to maximize their use.<sup>33-35</sup> Furthermore, the use of evidence-based therapy in the

acute MI setting is strongly associated with lower 6-month mortality.<sup>36</sup>

## REGIONAL VARIATION OF PROCEDURE USE

This study demonstrates that regional variation influences the type of LV assessment performed. Patients with MI in the United States and Canada underwent cardiac catheterization more often than those in other regions; in other regions, echocardiography was done more often. In all regions except Australia and New Zealand, at least 75% of patients underwent either echocardiography or cardiac catheterization. Procedure use may reflect regional practice, access to procedures, or differences in reimbursement. Echocardiography is an accessible tool compared with cardiac catheterization and provides a means for determining needed intensity of care. Although observational studies have not demonstrated a difference in mortality between patients at hospitals with or without on-site cardiac catheterization, the use of invasive procedures is significantly higher at hospitals with on-site catheterization.<sup>37,38</sup> Risk stratification in hospitals without on-site cardiac catheterization could be done with echocardiography instead. However, at least in the United States, this has not appeared to be the case in previous studies.<sup>39</sup> While LV assessment seems to be suboptimal, it is important to recognize that all sites were VALIANT clinical trial sites. Therefore, the frequency in our study is likely to be greater than the rate in true regional practice as evidenced by the Global Registry of Acute Coronary Events (GRACE) study.<sup>23</sup>

## LIMITATIONS

Because this is an observational study, our results have several potential limitations. We did not collect details of the echocardiogram or cardiac catheterization, nor do we know how information from the procedures was used, if at all. The timing of the procedures in relation to MI symptom onset was not recorded; procedures may have been deferred to outpatient follow-up. Although initial LV dysfunction after MI is often followed by some recovery due to reversal of myocardial stunning, the ideal timing of post-MI evaluation of LV systolic function remains unclear.<sup>40-42</sup> Confounding related to early deaths may have influenced the findings, although our analyses attempted to limit this. While we attempted to adjust for clinical factors associated with having LV assessment, the propensity analysis is limited to the data available, which likely leaves residual confounding. Lastly, the sites conducting the registry were involved in a clinical trial, and they may not represent generalized care. However, this bias tends to be associated with greater use of procedures and evidence-based medicine.

In conclusion, left ventricular assessment with either echocardiography or cardiac catheterization is frequently not performed in the United States and other countries during the in-hospital stay in evaluating patients with an acute MI, including those complicated by HF. It is associated with other quality-of-care markers such as appropriate medication use and lower in-hospital mortality.

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