Validation in a Community Hospital Setting of a Clinical Rule to Predict Preserved Left Ventricular Ejection Fraction in Patients After Myocardial Infarction

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Background: A previous study showed that patients with previous myocardial infarction (MI) who meet 4 simple clinical and/or electrocardiographic criteria have a left ventricular ejection fraction (LVEF) of 40% or greater, with a positive predictive value of 98%. The objective of this study was to validate this clinical rule in the community hospital setting.

Methods: Retrospective chart review in a 330-bed community hospital. Two hundred thirteen consecutive patients with MI were identified between June 1, 1993, and March 31, 1995. Left ventricular ejection fraction was predicted in a blinded fashion by means of the clinical rule before the actual LVEF test was reviewed.

Results: We identified 213 patients admitted with the primary discharge diagnosis of acute MI. All patients met standard clinical and enzymatic definitions for acute MI and had at least 1 measure of LVEF, such as echocardiography, ventricular angiography, or gated blood pool scan. The clinical rule predicted that 83 patients (39.0%) would have an LVEF of 40% or greater. Of these 83 patients, 71 had an ejection fraction of 40% or greater, for a positive predictive value of 86%. Of the 12 patients who were incorrectly predicted to have a preserved LVEF, 6 (50%) had an index non–Q-wave anterior MI ($P<.001$). Reanalyzing the patient population with a fifth variable (anterior non–Q-wave MI) added to the original 4 variables increased the positive predictive value to 91%.

Conclusions: This simple clinical prediction rule has a positive predictive value of 86% when applied in the community hospital setting. Patients with anterior non–Q-wave MI may be 1 group in whom the rule is inaccurate, and expanding the clinical rule to 5 variables may increase the positive predictive value. When a technology-based assessment of left ventricular function is considered in patients after an MI, this prediction rule may allow for a more cost-effective patient selection, and as many as 40% of patients who have had acute MIs may require no testing at all.

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THE USEFULNESS of determining the left ventricular ejection fraction (LVEF) in patients who have had a myocardial infarction (MI) has been well studied.[1-3] A documented LVEF of less than 40% has been shown to be a statistically meaningful predictor of mortality in these patients.[4] Knowledge of LVEF in patients after MI also guides pharmacological therapy. Several large studies have clearly shown that angiotensin-converting enzyme inhibitors positively influence survival in patients with left ventricular failure.[5-8] Others[9] have suggested that anticoagulation is beneficial in the subset of patients with an anterior wall MI and a reduced LVEF.

The most recent indicators from the Health Care Financing Administration (HCFA) for the hospital treatment of acute MI (AMI) have implied that knowledge of LVEF after MI is critical for prognostication and therapy.[10] A strict interpretation of this document would indicate that, before discharge, all patients should undergo an LVEF determination, by either invasive or noninvasive methods. Following this recommendation on a routine basis would lead to approximately 600 000 LVEF tests being done each year in patients with AMI.[11]

Several studies with information attained at the bedside have been published documenting efforts to predict poor left ventricular function. These predictive models, which rely on clinical, historical, and/or electrocardiographic (ECG) data, are limited because of their large degree of error.[12-17] Also, these models frequently used mathematical formulas that are too cumbersome to be easily incorporated into simple bedside diagnostics.

Silver et al[18] recently defined a clinical rule that predicts preserved LVEF in patients after MI with a positive predic-

PATIENTS AND METHODS

PATIENTS AND STUDY LOCATION

The study was performed at Botsford General Hospital, a 330-bed community teaching hospital in Farmington Hills, Mich. Medical records with a primary discharge diagnosis of AMI[19] were identified and reviewed. All patients had to survive beyond the emergency department to be eligible for the study. Patients were excluded if they had either a perioperative MI or a coexisting terminal illness. Two hundred thirteen consecutive patients who met the standard diagnosis of AMI between June 23, 1993, and March 7, 1995, were included. There were 293 patients initially identified and reviewed, 65 of whom were excluded because they failed to meet our AMI criteria. Another 14 were rejected because they did not have an LVEF determination during initial hospitalization, and 1 was excluded because his only LVEF determination was by 2-dimensional echocardiography and his study was unavailable for re-review.

DATA COLLECTION

Data were obtained through collection forms based on previously defined clinical and historical information.[18] As much as possible, ECG and historical information was retrieved from progress notes before data regarding measured LVEF were abstracted from test results. This was done to reduce potential bias in assigning clinical designation based on measured LVEF. The patient's ECG on initial examination was used for clinical rule algorithm.

DEFINITION OF AMI

Patients were given the discharge diagnosis of AMI if they had increases in their creatine kinase–MB index to 3% or more of the total and either had a history compatible with MI or had new ECG abnormalities (defined below).

The following ECG criteria for the designation of AMI were used: (1) *Q waves* were defined as a negative initial deflection in the QRS complex of at least 1 mV in amplitude and 40 milliseconds in duration; (2) *ST-segment elevation and depression* were defined as a deflection of at least 1 mm from the baseline PR segment, 80 milliseconds after the J point; (3) *T-wave inversion* was defined as a complex of at least 1 mm below the baseline PR segment; (4) *left bundle-branch block* was defined as a QRS duration of at least 110 milliseconds, with a typical QRS morphological pattern in leads V_1 and V_6; and (5) *left ventricular hypertrophy with QRS widening* was defined as a QRS duration of at least 110 milliseconds with associated typical repolarization abnormalities consistent with strain in the presence of standard voltage criteria for left ventricular hypertrophy.[20] The ECG changes were classified according to the standard nomenclature for anterior (leads V_1-V_4), inferior (II, III, aVF), apical (V_5-V_6), lateral (I, aVL), and posterior (R wave in V_1-V_2) walls.

Congestive heart failure was defined as historical if the patient had a previous episode thereof, or new onset if 1 or more of the following criteria were satisfied: alveolar edema on a current chest radiograph, current physical examination findings consistent with pulmonary edema, or dypsnea alleviated with diuretics.

DETERMINATION OF LVEF

The ejection fraction was assessed by 1 or more of the following 3 modalities: transthoracic echocardiography, contrast ventriculography, and radionuclide ventriculography. For patients who had more than 1 modality to assess their LVEF, the following ranking of tests was followed: (1) echocardiography; if not available, then (2) contrast ventriculography; if not available, then (3) radionuclide ventriculography.

All echocardiographic ejection fractions were confirmed with visual assessment by 1 of 2 cardiologists (R.S. and D.H.) who were blinded to the study data.

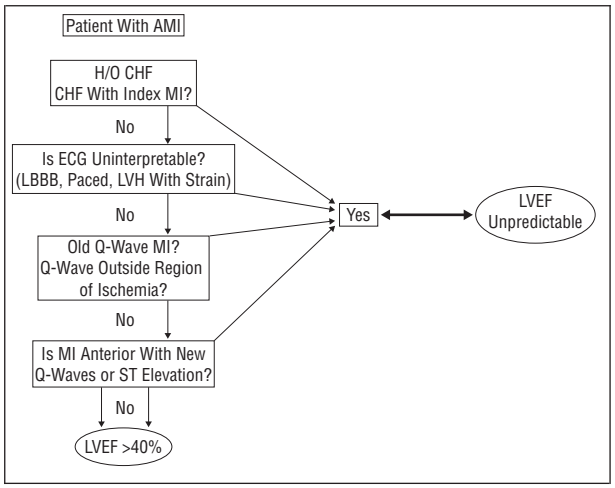
tive value (PPV) of 0.98 (95% confidence interval [CI], 0.90-0.99). This clinical rule was determined from a cohort of 314 patients admitted to a tertiary care center with a diagnosis of AMI between January 1, 1992, and October 31, 1992. This clinical rule was derived in the first 162 patients and then validated in the remaining 152 patients. It relies on 1 historical variable—the absence of congestive heart failure either in the past or with the index MI—and 3 ECG variables: an interpretable ECG (absence of left bundle-branch block, ventricular pacing, or left ventricular hypertrophy with strain); absence of Q waves outside the region of the AMI; and absence of anterior Q waves with this MI (**Figure**).

Because the clinical rule was derived from a large tertiary center population, we were anxious to see if it would be applicable in the community hospital setting. Tertiary care centers tend to have referral bias and therefore more acutely ill patient populations when compared with community hospitals. This article describes the application of this clinical rule in 213 consecutive patients who came to a community hospital with an AMI.

RESULTS

Two hundred thirteen (127 men and 86 women) patients with the primary discharge diagnosis of AMI were entered in the study. Mean (±SD) age was 67 ± 13 years; 63 ± 18 years for men and 73 ± 12 years for women. Ninety patients (42.3%) had an acute Q-wave MI, of whom 64 (71%) met the standard criteria[21] and received thrombolysis (**Table 1**). Among 15 patients who were not included in the study, the mean age was 64 ± 11 years; 11 were male; 8 had a Q-wave MI; and 6 met the clinical rule criteria for preserved left ventricular function.

Among the 213 study patients, 167 underwent echocardiography, 48 had contrast left ventriculograms, and 5 underwent radionuclide ventriculograms. Four patients had both an echocardiogram and a left ventriculogram; 1 had both an echocardiogram



Clinical rule to predict preserved left ventricular ejection fraction (LVEF) in patients after acute myocardial infarction (AMI). H/O CHF indicates history of congestive heart failure; MI, myocardial infarction; ECG, electrocardiogram; LBBB, left bundle-branch block; and LVH, left ventricular hypertrophy.

and a gated blood pool scan; and 1 patient had all 3 tests.

There were 130 patients for whom the clinical rule suggested an indeterminate LVEF. The remaining 83 patients met all 4 clinical criteria and were expected to have an LVEF of 40% or more. Of these 83 patients, 71 actually had an LVEF of 40% or more, for a PPV of 0.86 (95% CI, 0.78-0.94).

Subset analysis of the 12 patients who were incorrectly predicted to have preserved LV function (**Table 2**) showed that patients with an anterior non–Q-wave MI were most likely to be misclassified ($P<.001$). Otherwise there were no significant differences between these 2 groups with regard to age, sex, peak creatine kinase level, or treatment with thrombolysis. When logistic regression modeling was used to further identify characteristics associated with misclassification of these patients, anterior non–Q-wave MI maintained significance (odds ratio, 6.43; 95% CI, 1.03-40.26; $P>.05$, χ^2 analysis).

COMMENT

In a previous publication, Silver et al[18] defined a clinical prediction rule for LVEF in patients who have had MI. In this study, we attempted to validate their original findings by testing this rule in a community hospital. In this population, the PPV was 0.86 (95% CI, 0.78-0.94), which is less than the original findings of 0.98 (95% CI, 0.90-0.99), although the CIs do overlap.

The 86% specificity of our clinical rule is not dissimilar from results of other current tests commonly used to guide important clinical decisions. For comparison, consider that routine exercise stress testing has a sensitivity of 56% to 81% and a specificity of 72% to 96%.[22-25] Screening mammography is reported to have a sensitivity of 82% and a specificity of 92%.[26] Both of these routine tests are considered to be within the standard of care in most medical communities and have similar statistical accuracy to our clinical rule.

Our preliminary subset analysis suggests that it may be possible to increase the PPV by adding a fifth variable. When the data were reanalyzed with the addition of a fifth variable—anterior non–Q-wave MI—70 patients were predicted to have preserved left ventricular function, of whom 64 actually did, for a PPV of 91%. The tradeoff for this increased specificity is that only 33% of the population would forgo routine LVEF testing instead of 39% as when the original 4-variable rule was applied.

Our high PPV is obtained at the cost of a low negative predictive value. Patients who are classified as having an unpredictable LVEF may or may not have impaired systolic function. However, the usefulness of the clinical rule is in the ability to accurately identify a subgroup of patients with AMI who have an LVEF of 40% or more.

Our patient demographics (Table 1) are similar to those of other community hospitals in the United States, as shown by the National Registry of Myocardial Infarction 2 Investigators.[27] Their patient population (N = 84 633), in which 76% of eligible patients received thrombolysis, was 67% male and had an overall mean age of 64 years. This is important as it shows that our findings in a single community hospital may reflect those in other similar centers across the country.

Table 1. Demographics of the Study Population*

Characteristic	Finding (N = 213)
Sex, No. (%)	
Men	127 (60)
Women	86 (40)
Transferred to tertiary referral center, No. (%)	34 (16)
Thrombolytic, No. (%)	64 (71)†
Q-wave MI, No. (%)	90 (42)
Non–Q-wave MI, No. (%)	123 (58)
CK, U/L	1139 ± 1261 (967-1307)‡
Age, y‡	
Total	67 ± 13 (66-69)
Men	63 ± 18 (61-66)
Women	73 ± 12 (70-75)

**MI indicates myocardial infarction; CK, creatine kinase.*
†Percentage of patients with Q-wave MIs who received thrombolysis, not percentage of total MI population.
‡Mean ± SD (95% confidence interval).

Table 2. Characteristics of Patients Accurately Predicted to Have Preserved Left Ventricular Function vs Misclassified Patients*

Variable	Misclassified (n = 12)	Correct (n = 71)	*P*
Anterior non–Q-wave MI, No. (%)	6 (50)	7 (10)	<.001
Non–Q-wave MI, No. (%)	9 (75)	22 (31)	.02
Q–wave MI, No. (%)	3 (25)	31 (44)	.22
Female sex, No. (%)	6 (50)	24 (34)	.28
Peak CK, mean ± SD, U/L	1342 ± 1574	993 ± 949	.30
Lytics, No. (%)	3 (25)	25 (35)	.49
Age, mean ± SD, y	62 ± 14	62 ± 12	.78

**MI indicates myocardial infarction; CK, creatine kinase.*

Table 3. LVEF Modality Assessment Comparison Between the Original Validation Project* and the Current Study†

	No. (%)		
	Original Project (N = 314)	Current Study (N = 213)	*P*
Echocardiogram	200 (64)	167 (78)	<.001
Left ventriculogram	187 (60)	48 (23)	<.001
MUGA	37 (12)	5 (2)	<.001

*Data from Silver et al.[18]
†LVEF indicates left ventricular ejection fraction; MUGA, multiple gated image acquisition analysis.

As expected, there were more nuclear and contrast ventricular studies in the original report than in the current patient population (**Table 3**). Of the 6 patients who had more than 1 LVEF testing modality performed, no misclassifications occurred. Although this is too small a subpopulation to allow us to draw any firm conclusions, it does support the original study findings, which showed that using echocardiography for determining left ventricular function results in a very low misclassification rate when compared with other criterion standard techniques.[18] With respect to echocardiography and patients with AMI, Jensen-Urstad and colleagues[28] recently showed that in patients treated with or without thrombolysis, visual estimation of LVEF by transthoracic echocardiography has an acceptable correlation with gated radionuclide studies and is as accurate as, or more accurate than, measured echocardiographic values in this specific population.

We believe that application of this clinical rule may allow for a more cost-effective use of potentially expensive tests currently used to measure LVEF. As many as 30% to 40% of patients with AMI may not require testing if they meet the clinical rule. From a cost-effectiveness standpoint, if 30% to 40% of the 600 000 patients in the United States who are hospitalized each year for MI[11] did not undergo routine LVEF studies, the projected savings would be striking.

Ironically, not performing routine LVEF assessment in patients after MI might currently be considered evidence of poor quality of care, as set forth by the HCFA project. The HCFA recently audited patient records from hospitals nationwide for certain critical indicators of quality and published AMI treatment standards from their findings. The HCFA criteria state that knowledge of LVEF is essential to planning therapy and stratifying future event risk. A strict interpretation of this indicator may lead one to order technological LVEF measurements in all MI survivors. However, if our clinical prediction rule is validated in large databases, then this routine strategy is not only unnecessary, but costly as well.

The limitation in our study is mainly its retrospective design. The possibility of bias is always a concern in this type of data collection. Because all nonechocardiographic and non-LVEF data were collected before the particular LVEF study was reviewed, we believe that we have minimized this potential ascertainment bias.

One other limitation may have been our failure to separate out patients who had congestive heart failure caused by systolic dysfunction from those who had only diastolic dysfunction. Conceivably, patients predicted by the clinical rule to have an LVEF less than 40% may indeed have underlying preserved left ventricular function. Since diastolic dysfunction may be present in some degree in up to 90% of patients with coronary artery disease,[29] making an accurate diagnosis of diastolic dysfunction as the primary cause of congestive heart failure in the setting of an AMI would be difficult.

As described previously,[18] the timing of LVEF assessment was not controlled for, other than that it had to be assessed before the initial hospital discharge. A separate study controlling for the specific timing of LVEF assessment would help determine if this is a statistically significant study limitation. Stunned myocardium could play a role in the misclassification of patients if periinfarction LVEF is assessed before all viable myocardial tissue has recovered.

Selvester and colleagues[30] published a validated QRS scoring system algorithm for defining the percentage of infarcted myocardium during an AMI. This system uses 32 ECG-based points in which each point equates to approximately 3% of the total left ventricular myocardium. This system also has ECG exclusion criteria similar to our clinical rule, including left bundle-branch block, left ventricular hypertrophy with strain, and a paced rhythm. Both the Selvester et al system and another ECG-based prediction model, the Cardiac Infarction Injury Scores, have been well validated.[31-33] A limitation of both systems for patients with AMI is the poor correlation of global ejection fraction in inferior MIs.[34] A separate study that uses either the Selvester scoring system or the Cardiac Infarction Injury Scores, along with the clinical rule for enhanced statistical accuracy, may be reasonable.

For the clinical prediction rule to be used effectively, it must be applied in the right population. Patients with known factors that might contribute to a reduced ejection fraction, such as severe valvular disease or a cardiomyopathy, should be excluded from this type of analysis. Clinical decision making should always supersede any standardized algorithm, and if the physician believes that further testing is warranted, it should be performed.

In conclusion, although our PPV decreased from 0.98 to 0.86, we believe that this clinical rule may be a valuable tool for post-MI clinical assessment. Further studies are needed with the inclusion of a fifth variable, anterior non–Q-wave MI, to see if this consistently increases the PPV as we have shown in this analysis.

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