Prediction of Outcome after Percutaneous Coronary Intervention for the Acute Coronary Syndrome

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BACKGROUND: The seven-component Thrombolysis In Myocardial Infarction (TIMI) score has been used to risk stratify, and to guide the medical management of, patients with unstable angina or non-ST-elevation myocardial infarction. We assessed the usefulness of the risk score in predicting in-hospital and 30-day outcomes in such patients who were undergoing percutaneous coronary intervention.

METHODS: Using the TIMI score, 2501 patients with unstable angina or non-ST-elevation myocardial infarction were divided into low-risk (zero to two risk factors; $n = 974$), intermediate-risk (three to four risk factors; $n = 1339$), and high-risk (five to seven risk factors; $n = 188$) groups, and outcomes were compared.

RESULTS: Angiographic/clinical success and the rate of minor procedural events were similar among the three groups. A higher TIMI risk score was associated with more cardiac comorbid conditions and more complicated angiographic lesions: longer lesions ($P = 0.0009$), more thrombotic lesions ($P =$

0.03), more multivessel disease ($P < 0.0001$), and more American College of Cardiology/American Heart Association type B2/C lesions ($P = 0.05$). Although the risk score did not predict interventional technical success or intraprocedural complications, a high score was associated with prolonged hospital stay, higher postprocedural peak troponin levels, and 30-day major adverse cardiac events. Stepwise logistic regression showed that in conjunction with lesion length and patient sex, a high score was an independent predictor of 30-day major adverse cardiac events (odds ratio = 2.3; 95% confidence interval: 1.1 to 4.1; C statistic = 0.62).

CONCLUSION: Although a higher TIMI risk score in patients with unstable angina or non-ST-elevation myocardial infarction who were undergoing percutaneous coronary intervention correlated with adverse clinical outcome, the score alone cannot be used to guide diagnostic or therapeutic strategies. *Am J Med.* 2003;115:708–714. ©2003 by Excerpta Medica Inc.

The risk of death or ischemic events in patients with unstable angina or non-ST-segment elevation myocardial infarction varies widely due to the heterogeneous nature of the disease. Risk stratification of these patients is essential for predicting prognosis, planning treatment strategy, and providing information to patients and relatives. The severity of the clinical presentation influences the type of treatment, such as use of platelet glycoprotein IIb/IIIa inhibitors or percutaneous coronary intervention, as patients with variable degrees of risk may differ considerably in the extent of benefit gained from specific interventions (1,2). The Thrombolysis In Myocardial Infarction (TIMI) investigators developed a risk score for adverse outcome based on seven predictors in patients in the TIMI-11B and Efficacy and Safety of Subcutaneous Enoxaparin in Non-Q-Wave Coronary Events (ESSENCE) trials (3). The TIMI risk score is commonly used for risk stratification and thera-

peutic decision-making in patients with unstable angina or non-ST-segment elevation myocardial infarction (1), who show considerable variability in terms of periprocedural enzyme release, hospital stay, and other ischemic events (4–7). However, it is not known if this risk score can also be used to predict outcomes in these patients. In the present study, we assessed the utility of the TIMI risk score in predicting procedural, in-hospital, and 30-day outcomes in patients with unstable angina or non-ST-segment elevation myocardial infarction who were undergoing percutaneous coronary intervention.

METHODS

Patients

Patients with unstable angina or non-ST-segment elevation myocardial infarction who had undergone percutaneous coronary intervention at Mount Sinai Hospital, New York, from July 1999 to May 2001, were identified from the hospital's interventional database. The TIMI risk score was calculated using the following established clinical variables: age ≥ 65 years, three or more coronary risk factors (diabetes, hypertension, hyperlipidemia, smoking, positive family history), known coronary stenosis $\geq 50\%$, ST-segment deviation at presentation, two or more anginal events in the last 24 hours, use of aspirin

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Table 1. Distribution of Patients by TIMI Risk Score and Individual Score Components

TIMI Risk Score	No. of Patients	Age ≥ 65 years	Aspirin Use in Last 7 Days	≥ 3 Coronary Risk Factors*	Known Coronary Stenosis $\geq 50\%$	≥ 2 Anginal Events in Last 24 Hours	Elevated Cardiac Marker Levels	ST-segment Deviation at Presentation
Number (%)								
0	28	0	0	0	0	0	0	0
1	238	47 (20)	107 (45)	34 (14)	14 (6)	3 (1)	29 (12)	4 (2)
2	708	303 (43)	529 (75)	284 (40)	165 (23)	41 (6)	70 (10)	24 (3)
3	844	515 (61)	717 (85)	512 (61)	492 (58)	114 (14)	116 (14)	66 (8)
4	495	374 (76)	456 (92)	391 (79)	397 (80)	206 (42)	89 (18)	67 (14)
5	157	136 (87)	152 (97)	137 (87)	139 (89)	134 (85)	51 (32)	36 (23)
6/7	31	29 (94)	31 (100)	30 (97)	29 (94)	29 (94)	23 (74)	15 (48)
Total	2501	1404 (56)	1992 (80)	1388 (56)	1236 (49)	527 (21)	378 (15)	212 (8)

* Risk factors include diabetes, hypertension, hyperlipidemia, smoking, and positive family history.

TIMI = Thrombolysis In Myocardial Infarction.

within the previous 7 days, and elevated levels of cardiac markers (Table 1). Patients received 1 point for each risk factor, with a maximum score of 7 and a minimum score of 0. Low risk was defined as zero to two risk factors, intermediate risk was defined as three to four risk factors, and high risk was defined as five to seven risk factors (3). Serial electrocardiograms were taken and cardiac enzyme levels (creatinine kinase-MB, troponin I) were measured before and after coronary intervention. Patients were followed for in-hospital cardiac and ischemic events. All patients were followed clinically for events at 30 days by telephone call to the patient or private physician. Interventions involved use of conventional technique, aspirin, clopidogrel, low-dose heparin (60 IU/kg), or glycoprotein IIb/IIIa inhibitors (4). The study was approved by the hospital's Institutional Review Board.

Definitions

Creatine kinase-MB isoenzyme levels were measured using the mass technique; elevated values were defined as levels ≥ 16 U/L, which were further divided into one to three times, four to five times, and greater than five times the baseline value. Troponin I levels ≥ 2.0 ng/mL were considered elevated. Procedural events were defined as angiographic dissection, side branch closure, distal thromboembolism, slow flow/no flow, and persistent chest pain. Angiographic success was defined as $<30\%$ diameter obstruction postprocedurally with TIMI III flow, and clinical success as indication of angiographic success of at least one lesion without urgent bypass surgery, Q-wave or large non-Q-wave myocardial infarction, or in-hospital death. Major adverse cardiac events at 30 days were defined as death, repeat intervention, or new myocardial infarction with creatine kinase-MB levels more than three times the baseline value.

Statistical Analysis

The data were analyzed with JMP 5.1a (SAS Institute, Cary, North Carolina) and SPSS 11.0 (Chicago, Illinois).

Categorical variables were compared using the chi-squared test. Comparisons of continuous variables, which did not violate normality assumption (as assessed by the Kolmogorov-Smirnov-Lilliefors test), were performed using analysis of variance. The Kruskal-Wallis test was used to compare nonnormally distributed continuous variables. All continuous data are expressed as means $\pm$ SD unless they violate normality assumption, in which case the data are presented as medians with the interquartile range.

Logistic regression models were used to examine the relation of TIMI risk groups to outcomes. The TIMI score was converted into a categorical variable (high risk vs. non-high risk) because of its nonlinear relation with 30-day major adverse cardiac events. We performed forward logistic stepwise regression using TIMI scores and pre-procedural patient and angiographic data, including sex, artery, left ventricular ejection fraction, stenosis, lesion length, American College of Cardiology/American Heart Association (ACC/AHA) lesion type, glycoprotein IIb/IIIa inhibitor use, TIMI flow, and aspirin or beta-blocker use. Age, diabetes, hypertension, smoking, and hyperlipidemia were excluded from the model because they are already included in the TIMI risk score calculation and pose a problem with covariate collinearity for the prediction of 30-day major adverse cardiovascular events. Univariate logistic regression was first performed for each covariate (8). Covariates with a significance level of $P < 0.20$ were entered into the multivariable model. A backwards elimination procedure (cutoff of $P > 0.10$) was then used to arrive at a final regression model. The initial model showed that lesion length is a significant covariate as a continuous variable. We converted lesion length into a categorical variable after determining that a cutoff of 12 mm would minimize the residual log likelihood chi-square, using recursive partitioning as implemented in SAS/JMP (9). The reported P value of the optimally di-

Table 2. Baseline Characteristics of Patients by Risk Group

Characteristic	Low Risk (n = 974)	Intermediate Risk (n = 1339)	High Risk (n = 188)	P Value
	Number (%) or Mean $\pm$ SD			
Age (years)	62 $\pm$ 12	68 $\pm$ 11	74 $\pm$ 9	<0.0001
Male sex	682 (70)	884 (66)	113 (60)	0.03
Diabetes mellitus	273 (28)	643 (48)	122 (65)	<0.0001
History of hypertension	760 (78)	1232 (92)	184 (98)	<0.0001
History of hyperlipidemia	623 (64)	1044 (78)	156 (83)	<0.0001
Prior myocardial infarction	117 (12)	549 (41)	115 (61)	<0.0001
≥ 2 Anginal events	44 (5)	320 (24)	163 (87)	<0.0001
Left ventricular ejection fraction (%)	54.6 $\pm$ 9.4	51.9 $\pm$ 11.4	49.8 $\pm$ 11.8	<0.0001
ST-segment deviation	28 (3)	133 (10)	51 (27)	<0.0001
Elevated cardiac markers	99 (10)	205 (15)	74 (39)	<0.0001
Low-density lipoprotein >100 mg/dL	506 (52)	723 (54)	120 (64)	0.01
Current smokers	175 (18)	187 (14)	19 (10)	0.01
Prior aspirin use	636 (65)	1173 (88)	183 (97)	<0.0001
Beta-blocker use	448 (46)	857 (64)	139 (74)	<0.0001
ACE inhibitor use	273 (28)	616 (46)	113 (60)	<0.0001
Statin use	487 (50)	897 (67)	143 (76)	<0.001

ACE = angiotensin-converting enzyme.

chotomized lesion length variable would be artificially low when compared with the original continuous lesion length variable. Model discrimination was assessed by C statistic, which is equivalent to the area under the receiver operating characteristic curve. We tested our model calibration with the Hosmer-Lemeshow goodness-of-fit test. Significance of each covariate was tested using the Wald statistic. C statistic comparison was performed using the DeLong nonparametric Mann-Whitney test (10) based on an SAS macro (version 8.02; Cary, North Carolina) written by DeLong. A *P* value <0.05 was considered significant.

RESULTS

A total of 2501 consecutive patients were analyzed, of whom 974 (39%) were in the low-risk, 1339 were in intermediate-risk (54%), and 188 (8%) were in high-risk groups (Table 2). There were more women in the high-risk group than in the low- and intermediate-risk groups (*P* = 0.03). Patients in the higher-risk group had lower left ventricular ejection fraction (*P* <0.0001) than did patients in the lower-risk groups, as well as used beta-blockers, angiotensin-converting enzyme inhibitors, and statins more frequently (all *P* <0.001).

Associations between Risk Group and Angiographic Variables

Patients in the high-risk group generally had more complicated lesions (Table 3) than did patients in the lower-

risk groups. They also were more likely to have ACC/AHA type B2/C lesions and longer lesions, as well as a higher prevalence of multivessel disease, thrombus, and a history of coronary artery bypass graft surgery. Saphenous vein grafts and in-stent restenosis were also more common in the high-risk group (Table 3). While pre- and postprocedural TIMI flow was not statistically different among the three risk groups, postprocedural minimum lumen diameter was slightly lower in the high-risk group (*P* = 0.05).

Procedural success rates were similar among the three risk groups (Table 4), even though different types of interventional devices were used. Stenting with or without rotational atherectomy was used in 77% in the low-risk group, 67% in the intermediate-risk group, and 63% in the high-risk group (*P* = 0.0006). Although the preprocedural use of glycoprotein IIb/IIIa inhibitors was higher in the high-risk group, use of these agents was lower in this group during percutaneous coronary intervention (Table 3), attributable to a higher incidence of saphenous vein graft and interventions for restenotic lesions. After adjusting for restenosis and bypass surgery, a high TIMI score appeared to be somewhat associated with increased intraprocedural glycoprotein IIb/IIIa inhibitor use (odds ratio [OR] = 1.37; 95% confidence interval [CI]: 0.8 to 2.3; *P* = 0.46). The maximum activated clotting time was similar in all groups (Table 3), with a comparable major vascular bleeding incidence of 1.1% (Table 4).

Table 3. Procedural Variables by Risk Group

Variable	Low Risk (n = 974)	Intermediate Risk (n = 1339)	High Risk (n = 188)	P Value
	Number (%) or Mean $\pm$ SD			
3-Vessel coronary artery disease	156 (16)	375 (28)	73 (39)	<0.0001
Previous coronary artery bypass graft surgery	70 (7)	356 (27)	84 (45)	<0.0001
Artery intervened				<0.0001
Left anterior descending	423 (43)	476 (35)	61 (32)	
Right coronary	236 (24)	355 (27)	45 (24)	
Circumflex	282 (29)	358 (27)	42 (22)	
Left main	2 (0.2)	13 (1.0)	5 (2.7)	
Saphenous vein graft	27 (3)	118 (9)	32 (17)	
Left internal mammary artery	3 (0.3)	13 (1.0)	2 (1.1)	
ACC/AHA type B2/C lesion	770 (79)	1085 (81)	162 (86)	0.05
Preprocedural TIMI flow <3	126 (13)	183 (14)	22 (13)	0.65
Postprocedural TIMI flow <3	46 (5)	65 (5)	7 (4)	0.88
Thrombus	11 (1)	28 (2)	6 (3)	0.03
Lesion length (mm)	12.4 $\pm$ 6.0	13.3 $\pm$ 6.6	15.2 $\pm$ 6.5	0.0009
Reference vessel size (mm)	3.2 $\pm$ 0.5	3.2 $\pm$ 0.5	3.2 $\pm$ 0.6	0.72
Preprocedural minimum lumen diameter (mm)	0.49 $\pm$ 0.36	0.45 $\pm$ 0.36	0.48 $\pm$ 0.36	0.30
Postprocedural minimum lumen diameter (mm)	2.96 $\pm$ 0.53	2.90 $\pm$ 0.62	2.88 $\pm$ 0.64	0.05
Preprocedural glycoprotein inhibitor use	146 (15)	174 (13)	45 (24)	<0.0001
Intraprocedural glycoprotein inhibitor use	721 (74)	964 (72)	103 (55)	<0.0001
Overall glycoprotein inhibitor use	867 (89)	1138 (85)	149 (79)	<0.0001
Intervention for restenotic lesions	51 (5)	284 (21)	64 (27)	<0.0001
Maximum activated clotting time (seconds)	283 $\pm$ 75	281 $\pm$ 75	287 $\pm$ 65	0.69

ACC/AHA = American College of Cardiology/American Heart Association; TIMI = Thrombolysis In Myocardial Infarction.

Associations between Risk Group and Outcome

Although the likelihood of minor procedural events was not statistically different among the three groups, patients in the high-risk group generally had greater increases in creatine kinase-MB levels, as well as higher peak and troponin I values, compared with the low- and

intermediate-risk groups (Table 4). In addition, longer hospital stays were more common ($P < 0.0001$) in the high-risk group, in whom the incidence of 30-day major adverse cardiac events was also higher, predominantly because of a trend towards greater creatine kinase-MB elevation.

Table 4. Outcome by Risk Group

Outcome	Low Risk (n = 974)	Intermediate Risk (n = 1339)	High Risk (n = 188)	P Value
	Number (%), Mean $\pm$ SD, or Median (Interquartile Range)			
Minor/major procedural complication	90 (9)	135 (10)	21 (11)	0.64
Major bleeding	11 (1.1)	17 (1.3)	2 (1.1)	0.93
Clinical success	958 (98.4)	1323 (98.8)	185 (98.4)	0.68
Any creatine kinase-MB elevation	196 (20)	228 (17)	52 (28)	0.006
Peak creatine kinase-MB (U/L)	7.2 (1.0–13.8)	7.7 (1.6–13.0)	8.8 (0.1–17.9)	0.08
Troponin I level $\geq$ 2.0 ng/mL	214 (22)	301 (23)	73 (39)	<0.001
Peak troponin I (ng/mL)	0.001 (0.00–1.40)	0.001 (0.00–1.80)	0.65 (0.00–5.70)	<0.001
Length of stay (days)	1 (1–1)	1 (1–1)	1 (1–2)	<0.0001
Postprocedural stay >1 day	218 (6)	77 (5)	90 (8)	<0.0001
30-Day major adverse cardiac events	60 (6)	70 (5)	19 (10)	0.03
Death	1 (0.1)	0	2 (1)	
Reintervention	7 (0.7)	11 (1)	3 (2)	
Myocardial infarction	52 (5)	59 (4)	14 (7)	

* Defined as creatine kinase-MB level more than three times the baseline value.

Table 5. Prolonged Length of Stay after Percutaneous Coronary Intervention and 30-Day Major Adverse Cardiac Events, by TIMI Risk Score

TIMI Risk Score	No. of Patients	Postprocedural Stay >1 Day*	30-Day Major Adverse Cardiac Event Rate†
0	28	25.0%	1.3%
1	238	26.9%	3.3%
2	708	20.8%	4.8%
3	844	24.1%	3.2%
4	495	30.0%	4.1%
5	157	45.2%	6.4%
6/7	31	38.7%	18.2%

* $P < 0.0001$; C statistic = 0.56.† For TIMI score: $P = 0.06$; C statistic = 0.53.

TIMI = Thrombolysis In Myocardial Infarction.

TIMI risk score correlated with the probability of a prolonged hospital stay (Table 5; $P < 0.0001$; C statistic = 0.56). Higher TIMI score was associated with increased 30-day major adverse cardiac events ($P = 0.06$), although a better logistic model fit could be obtained after cubic transformation of the TIMI score ($P = 0.01$). The relation between TIMI score and 30-day event rate is not linear because in the higher-risk group there is a disproportionately larger increase in cardiac event rate for every 1-point increase in TIMI score. The incidence of 30-day major adverse cardiac events for a TIMI score of 0 to 4 (low/intermediate risk) was similar, but statistically higher for a score of 5 to 7 (high risk) (Table 4; $P = 0.03$).

The logistic regression model (Table 6; $P < 0.0001$) revealed that a high TIMI score was a modest predictor of 30-day major adverse cardiac events (OR = 2.3; 95% CI: 1.1 to 4.1; $P = 0.01$). In conjunction with lesion length and sex, the model had a C statistic of 0.62.

DISCUSSION

We found that a higher TIMI risk score was associated with more cardiac comorbid conditions and more com-

Table 6. Multivariate Model of Major Adverse Cardiac Events at 30 Days

Variable	30-Day Major Adverse Cardiac Events*	
	Odds Ratio (95% Confidence Interval)	P Value
High TIMI score	2.30 (1.12–4.13)	0.01
Lesion length ≥ 12 mm	1.87 (1.20–2.95)	0.006
Female sex	1.43 (1.23–2.96)	0.004

* $P < 0.0001$ for model; C statistic = 0.62; $P = 0.86$ with Hosmer-Lemeshow goodness-of-fit test.

TIMI = Thrombolysis In Myocardial Infarction.

plicated angiographic lesions (longer lesions, more thrombotic lesions, more multivessel disease, and more ACC/AHA type B2/C lesions). Although the risk score did not predict procedural technical success or the likelihood of intraprocedural complications, it correlated with length of hospital stay and postprocedural enzyme release. The score alone was only very modestly predictive of 30-day major adverse cardiac events, although its discriminatory ability somewhat improved when used in conjunction with patient sex and lesion length.

Other studies of the prediction of postprocedural outcome, which included patients with ST-elevation myocardial infarction who were in cardiogenic shock as well as elective stable angina patients, have reported a C statistic ranging from 0.78 to 0.9 (11–14). The original study describing the derivation of the TIMI risk score reported a C statistic of 0.63 (3). Application of the risk score to the Veterans Affairs Non-Q-Wave Myocardial Infarction Strategies In-Hospital (VANQWISH) database (which consisted of non-ST-elevation myocardial infarction or unstable angina patients undergoing either conservative or aggressive therapy) showed that the TIMI risk score was substantially more predictive of events in the conservative strategy group (C statistic = 0.62) than in the invasive strategy group (C statistic = 0.53) (15). Similarly, we found that the TIMI risk score by itself was only very modestly predictive (C statistic = 0.53), but a simple modification incorporating three variables (TIMI score, lesion length, and sex) slightly improved predictive power (C statistic = 0.62). Although a higher score correlated with adverse clinical outcome, no combinations of factors are sufficiently predictive to guide diagnostic or therapeutic strategy.

Prior studies have identified various clinical (unstable angina, postinfarct angina, diabetes, left ventricular ejection fraction) and angiographic (multivessel disease, thrombus, calcified lesions, ACC/AHA B2/C lesions, vein graft lesion) characteristics as being associated with the risk of procedural, in-hospital, and short-term events after intervention (5–7). However, the risk factors vary throughout the literature, especially with the availability of newer devices and adjunctive pharmacotherapy, which have been reported to increase the procedural success of coronary intervention to over 96%, with slightly lower rates in patients with acute coronary syndrome and complex coronary lesion morphology as compared with stable patients (6). Therefore, it is important to identify high-risk patients undergoing percutaneous coronary intervention who could benefit from other adjunct pharmacotherapy such as low molecular weight heparin, glycoprotein IIb/IIIa inhibitors, or clopidogrel, in addition to appropriate interventional devices (2,16–23). The TIMI risk score was established to facilitate the triage of patients with acute coronary syndromes. In the Treat angina with Aggrastat and determine Cost of Therapy with

an Invasive or Conservative Strategy (TACTICS) trial, early angioplasty with a glycoprotein IIb/IIIa inhibitor (tirofiban) was superior to a conservative approach at 30 days and 6 months in patients with the acute coronary syndrome, especially those with elevated troponin levels and an intermediate-to-high TIMI risk score (24). We found that TIMI score alone was only modestly useful in predicting postprocedural outcome, and would need to be used in conjunction with other information, such as lesion length and patient sex, to have better predictive value.

The lower intraprocedural use of glycoprotein IIb/IIIa inhibitors in high-risk patients may be explained by the higher prevalence of older patients, who have an increased risk of vascular and nonvascular bleeding, and higher rates of saphenous vein graft and in-stent restenosis, where the use of these agents has been controversial (7,25). Periprocedural creatine kinase-MB elevation three times the normal occurs in 4% to 5% of patients and use of glycoprotein IIb/IIIa inhibitors has been shown to decrease enzyme release (6,7,17). Both creatine kinase-MB and troponin I elevation were higher in our high-risk group, perhaps due to increased distal thromboembolism, which can be further reduced by aggressive antiplatelet therapy and use of distal protection devices (25–27). We found that high-risk patients had a higher incidence of 30-day major adverse cardiac events, perhaps due to increased multivessel coronary disease and complex lesions, and lower left ventricular ejection fraction, as compared with low- or intermediate-risk patients, but none of these factors were independently predictive of 30-day major adverse cardiac events.

Prior beta-blocker therapy at the time of percutaneous coronary intervention has been shown to decrease periprocedural creatine kinase-MB release and long-term mortality (28). In our study, 74% of high-risk patients were receiving beta-blocker treatment before undergoing the procedure. Likewise, statin therapy has been shown to reduce 30-day and 6-month mortality (29). We found that despite statin use in about 65% of patients, the average low-density lipoprotein cholesterol level was 121 ± 11 mg/dL, suggesting that further measures should be adopted to reduce levels to <100 mg/dL.

Our study has several limitations. It was not randomized, and it employed the TIMI risk score retrospectively to predict the risk of outcomes after percutaneous coronary intervention. Patients were followed for only 30 days. C-reactive protein, an important inflammatory marker of adverse prognosis in patients with unstable angina or non-ST-segment elevation myocardial infarction, was not measured and not included in the risk calculation.

In conclusion, although the TIMI risk score has previously been shown to be useful in the risk stratification of acute coronary syndrome patients, it was only modestly

predictive in this group of patients undergoing percutaneous coronary intervention. The score alone cannot be used to guide interventional treatment strategy.

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