Prediction of Risk and Complications

A preprocedural risk model can help patients and health care providers alike.

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Predicting complications after percutaneous coronary interventions (PCI) is an increasingly important aspect of interventional cardiology and paramount toward management of issues related to quality assurance, patient strategies of care, institutional resources, and patient and family counseling (Table 1). An extensive body of literature continues to accrue about prediction of early as well as late events (Table 2).[1-13] Attempts at prediction must be tempered with the unavoidable fact that precise prediction of a specific event is not possible for an individual patient, because any discrete event either occurs or it does not.

Some potential events that have been studied with regard to prediction algorithms are seen in Table 2. For such events, ideal risk-score models should include simple and easily obtainable variables, predict morbidity and mortality rates, validated both internally as well as externally, and reflect contemporaneous technology used during procedures (Table 3).[1-13] In addition, it would be optimal to predict the outcomes of procedures without parameters that can only be obtained during the procedure.[1,3] For example, if specific angiographic or procedural details (left main, thrombus, multivessel disease, or number of stents used) are required

TABLE 1. INDICATIONS FOR RISK STRATIFICATION

• Compare outcomes between institutions/operators
• Identify opportunities for improvement
• Select therapy
• Study/develop new approaches
• Counsel patient/family
• Therapeutic options
• Longer-term outcome

TABLE 2. SPECIFIC OUTCOME EVENTS FOR PREDICTION

Early Events	Late Events
• Acute/threatened closure	• Mortality
• Q-wave MI	• Stent thrombosis
• Biomarker elevation	• Restenosis/target-vessel revascularization
• Mortality	• Myocardial infarction
• Emergency CABG	
• Renal failure	
• Central nervous system events	
• Vascular complications	

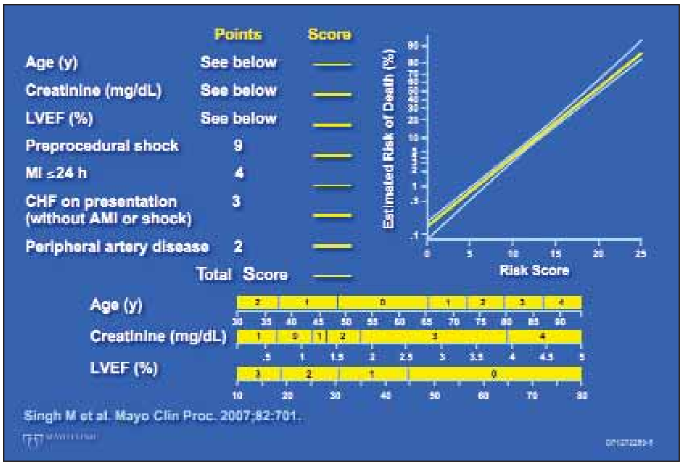

Figure 1. Estimated risk of in-hospital death as a function of Mayo Clinic risk score. (From *Mayo Clin Proc*,[1] with permission.)

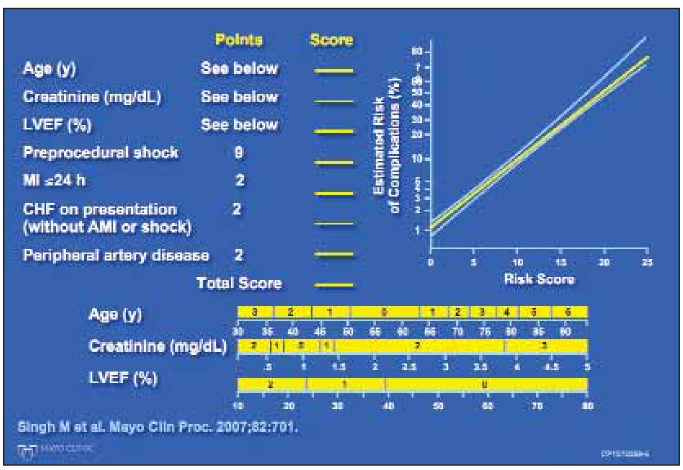

Figure 2. Prediction of in-hospital MACE as a function of Mayo Clinic risk score. (From *Mayo Clin Proc*,[1] with permission.)

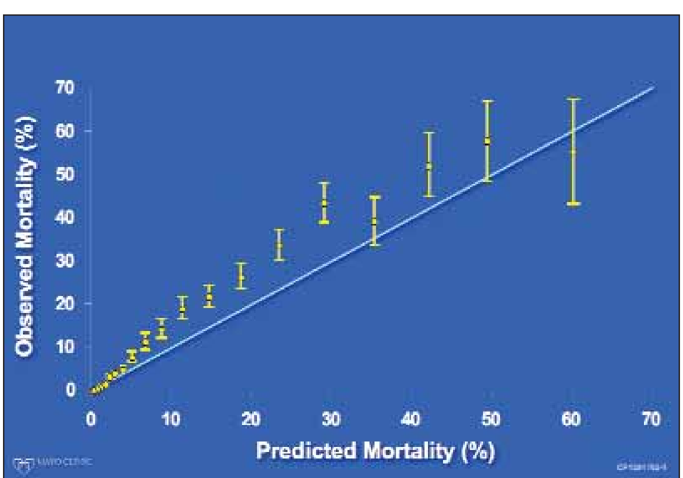

Figure 3. Results of observed versus expected in-hospital mortality in 309,351 patients in the NCDR.

TABLE 3. CHARACTERISTICS OF AN IDEAL RISK SCORE MODEL

- Simple and easily obtainable variables
- Predicts mortality and morbidity
- Validated internally and externally
- Reflects modern PCI practice
- Able to predict outcome without angiographic variables

for a periprocedural mortality risk score, it is then not practical to use such a prediction model for patient and family counseling before that specific procedure.

Prediction of mortality and major adverse cardiac event rates (MACE) has received the most attention, and there are now multiple risk scores available. Most of these include somewhat similar factors, although one key differentiation is the inclusion of baseline angiographic characteristics in some of the risk scores versus only clinical characteristics in others. We previously constructed a practical pre-PCI risk model for both in-hospital mortality and MACE rates based solely on a baseline clinical and noninvasive assessment that can serve as a simple risk assessment aid to patients and physicians before coronary angiography is performed.[1] This model was based on the outcome of 7,457 patients undergoing PCI at the Mayo Clinic from 2000 to 2005 (Table 4). Because this model only needs information from clinical and noninvasive variables available at the time of first contact, patient, family members, and health care providers can use the model in the process of obtaining informed consent. Information about risks from a revascularization procedure is critical in the planning stage before the patient is sent to the cardiac catheterization laboratory.

For this study, several variables were used, including preprocedural shock, myocardial infarction (MI) within 24 hours, male gender, age, creatinine level, ejection fraction, congestive heart failure, peripheral vascular disease, and diabetes mellitus. Seven of these variables were found to be significantly associated with both in-hospital mortality and MACE rates (Figures 1 and 2). The model performances in selected subgroups of these patients were excellent, with a c-statistic of .90 for procedural mortality and .76 for MACE rates, highlighting excellent discrimination. The models worked well in various predefined risk groups, including patients with diabetes mellitus, female gender, and multivessel disease.

With this model, risk categories can be used to stratify patients across the broad spectrum of risk from very low to very high for both in-hospital mortality as well as MACE rates. It is evident that the expected outcome in each category of risk was very similar to the observed outcome (Table 5).

TABLE 4. MODEL PERFORMANCES IN SELECTED SUBGROUPS OF 7,457 PATIENTS FOR PROCEDURAL DEATH/MACE

Variable	No. of Patients	Observed	Expected	C-Statistic Procedural Death/MACE
Acute MI/shock				
No	5,874	34/149	36/155	.80/.67
Yes	1,583	102/142	100/136	.89/.82
Age groups (y)				
<55	1,371	14/32	15/34	.91/.76
55–64	1,737	17/36	17/38	.93/.74
65–74	2,218	30/81	35/78	.83/.65
≥75	2,131	75/142	69/141	.88/.74
Gender				
Women	2,280	51/107	48/102	.87/.77
Men	5,177	85/184	88/189	.92/.75
Diabetes mellitus				
No	5,548	97/208	97/210	.91/.76
Yes	1,909	39/83	39/81	.89/.75

From *Mayo Clin Proc*,[1] with permission.

TABLE 5. FREQUENCIES AND EVENT RATES WITHIN RISK CATEGORIES

	Very Low	Low	Moderate	High	Very High
Death					
N	5,107	1,556	373	142	279
Score interval	0–4	5–7	8–10	11–13	14+
Expected %	<1%	1–2%	2–5%	5–10%	≥10%
Observed %	0.4%	1.1%	1.9%	9.2%	28.7%
MACE					
N	3,167	2,638	1,200	251	201
Score interval	0–2	3–5	6–9	10–13	14+
Expected %	<2%	2–4%	4–10%	10–20%	≥20%
Observed %	1.5%	2.8%	4.8%	15.1%	37.8%

From *Mayo Clin Proc*,[1] with permission.

TABLE 6. DISCRIMINATION OF THE MAYO CLINIC RISK SCORE MODEL USING THE NCDR REGISTRY			
Group	N	MCRS (min–max)	C-Index
Overall	309,351	0–25	.884
Shock/acute MI	69,920	4–25	.873
Age <40	5,627	1–21	.938
Age 65+	151,517	0–25	.858
CHF	27,003	3–25	.82
Creatinine <.7	10,491	1–20	.797
Creatinine >1.2	66,839	1–25	.875
Multivessel disease	150,579	0–25	.87
Female	104,110	0–24	.872
Diabetes	98,081	0–24	.878

Recently, this Mayo Clinic Risk Score (MCRS) was evaluated in the National Cardiovascular Data Registry (NCDR) using 309,351 patients treated between 2004 and 2006.[14] Nine variables (previously identified) had modest to excellent discrimination in patients undergoing PCI and were found to be significantly associated with in-hospital mortality (all <.0001). The c-statistic varied from .797 to .938, indicating excellent discrimination (Table 6). In this data set, the recalibrated model demonstrated excellent discrimination, and the observed versus the expected mortality can be seen in Figure 3. Risk scores, such as these that can predict mortality or even MACE rates before the procedure is initiated, are very valuable for patient and family counseling and for planning resource utilization.

We also established that the new MCRS, originally derived to predict outcomes following PCI using the preprocedure variables, could also predict in-hospital mortality rates after CABG surgery in the Society of Thoracic Surgeons database (in press). All the previous attempts in the risk model development were predicated on the selection of either surgical or percutaneous revascularization therapy. More recently, the New York state models for both PCI and CABG reported surprisingly similar risk factors such that seven of the 10 variables in

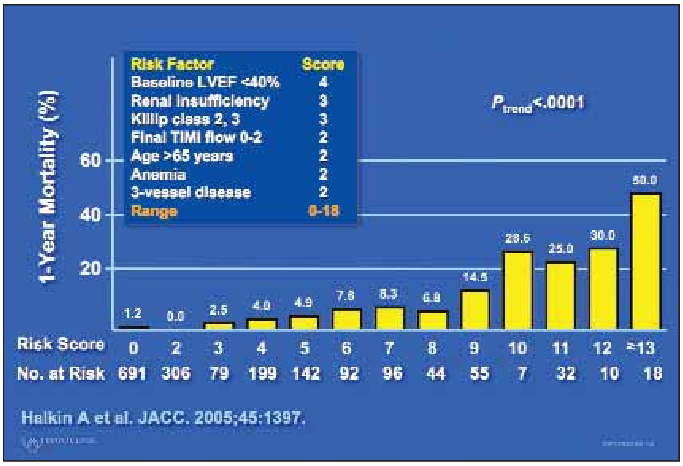

Figure 4. Data obtained using the CADILLAC and Stent PAMI trials documenting the relationship between specific risk factors and 1-year mortality. (Reprinted from Halkin A, Singh M, Nikolsky E, et al. Prediction of mortality after primary percutaneous coronary intervention for acute myocardial infarction: the CADILLAC risk score. *J Am Coll Cardiol*. 2005;45:1397-405, with permission from Elsevier.)

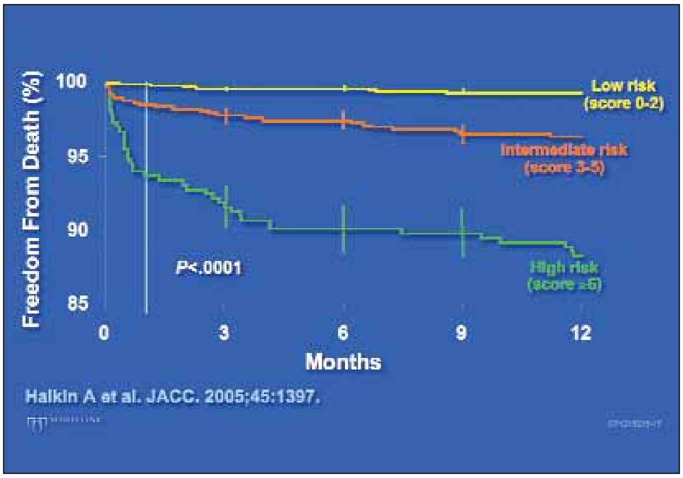

Figure 5. Multivariate predictors of freedom from all-cause mortality in patients enrolled in the CADILLAC trial broken down by tercile of risk. (Reprinted from Halkin A, Singh M, Nikolsky E, et al. Prediction of mortality after primary percutaneous coronary intervention for acute myocardial infarction: the CADILLAC risk score. *J Am Coll Cardiol*. 2005;45:1397-405, with permission from Elsevier.)

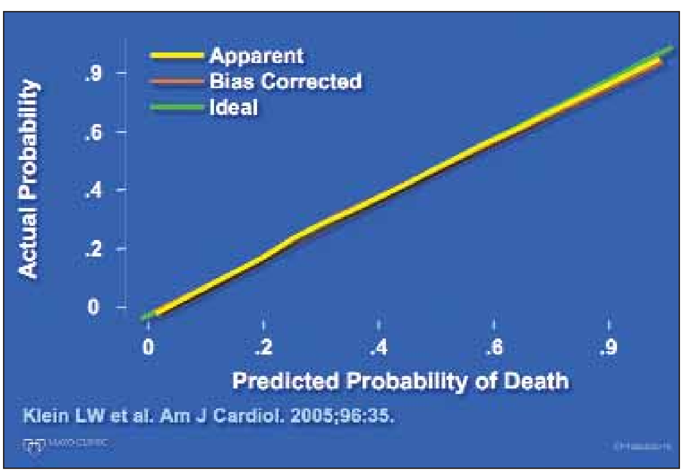

Figure 6. The highest-risk patients among acute ischemic syndromes are these with cardiogenic shock. The ACC-NCDR data set was used to develop a prediction model for mortality. (Reprinted from Klein LW, Shaw RE, Krone RJ, et al. Mortality after emergent percutaneous coronary intervention in cardiogenic shock secondary to acute myocardial infarction and usefulness of a mortality prediction model. *Am J Cardiol*. 2005;96:35-41, with permission from Elsevier.)

the CABG risk score were also listed in the PCI model and six out of seven listed MCRS risk variables are similar to the New York state model underscoring commonality of risk variables in prediction of outcome regardless of the revascularization strategy. The advantages of the current MCRS model include exclusion of subjective (urgency) or imaging (eg, extensively calcified aorta), variables minimizing collinearity, and inconsistencies in data collection. Second, age, ejection fraction, and serum creatinine levels are reported as continuous variables, allowing providers to calculate finer risk gradients. The present analyses created a window of opportunity to use a single risk score to assess the risk of coronary revascularization therapies based on easily obtainable demographic and laboratory parameters.

Mortality can also be predicted in higher-risk groups of patients. Halkin et al evaluated mortality rates after primary PCI for ST-elevation MI in the CADILLAC and Stent PAMI trials. In each trial, the 1-year mortality rate was 4.3%.[11] These investigators identified seven independent predictors using multivariate analysis, including baseline ejection fraction <40%, renal insufficiency, Killip Class 2/3, final TIMI flow grade 0 to 2, age ≥65 years, anemia, and the presence of multivessel disease (Figures 4 and 5). Each variable was assigned an integer score. One-year mortality was strongly correlated with that integer score (Figure 2), and using it, again low-, intermediate-, and high-risk patients could be separated. The receiver operating characteristics area was .81, also indicating excellent strength of the model.

Finally, the highest-risk patients are those with cardiogenic shock; risk modeling has also been evaluated for cardiogenic shock. In an earlier data set, Hasdai et al evaluated patients in the GUSTO 1 trial to identify risk factors associated with developing shock and then for mortality after the development of shock. More recently, this has also been studied in the ACC/NCDR data set of patients treated between 1998 and 2002. In this data set, the in-hospital mortality rate was high at 59.4%.[12] Factors associated with mortality prediction included age for 10-year increment, female gender, history of renal insufficiency, total occlusion of the left anterior descending artery, no stent used, and no glycoprotein IIb/IIIa inhibitor used during PCI. Again, an accurate nomogram was developed to predict death (Figure 6).

CONCLUSION

There has been significant progress toward model development for risk prediction after coronary revascularization procedures. With the availability of a prepro-

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cedural risk model for prediction of mortality regardless of the revascularization procedure used (CABG or PCI), risk stratification can help patients and health care providers to objectively assess the risks, facilitate in obtaining informed consent, provide objectively risk-adjusted comparisons, and counsel patients when coronary revascularization is considered. ■

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