

Preoperative Risk Evaluation in Beating-Heart Coronary Artery Bypass Surgery

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Introduction and objectives. Operative risk stratification scales for use in cardiac surgery have been developed for patients who undergo procedures using extracorporeal circulation. The aims of the present study were to investigate the use of six preoperative risk stratification scales in patients undergoing beating-heart surgery and to identify risk factors for major complications and mortality in our group of patients who underwent revascularization using this approach.

Patients and method. Between January 1997 and December 2002, we performed 762 coronary artery bypass operations on the beating heart; 61 patients suffered major complications (8%) and 25 died (3.3%). Risk factors for major complications and death were identified using logistic regression analysis of prospectively collected data. The following risk scores were calculated for each patient: Parsonnet 95, Parsonnet 97, Euroscore, Cleveland, Ontario, and French. Receiver operating characteristic curves were used to compare the ability of each scale to predict mortality and major complications.

Results. In our patient group, the preoperative variables associated with increased risk were: need for cardiopulmonary resuscitation, renal dysfunction, peripheral vasculopathy, and the presence of severe left main coronary artery disease, three-vessel disease, or an impaired ejection fraction.

Conclusions. Mortality and major complications were best predicted by the Parsonnet 95 and Euroscore scales.

Key words: *Revascularization. Risk factor. Surgery.*

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Evaluación preoperatoria del riesgo en la cirugía coronaria sin circulación extracorpórea

Introducción y objetivos. Los modelos de estratificación del riesgo quirúrgico en cirugía cardíaca han sido elaborados a partir de pacientes intervenidos con circulación extracorpórea. El objetivo del presente estudio es valorar cómo se comportan 6 modelos de riesgo preoperatorio en pacientes intervenidos sin circulación extracorpórea, así como conocer cuáles son los factores de riesgo predictores de complicaciones mayores y mortalidad en nuestros pacientes revascularizados mediante dicha técnica.

Pacientes y método. Entre enero de 1997 y diciembre de 2002 se realizó cirugía de revascularización miocárdica sin el uso de circulación extracorpórea en un total de 762 pacientes consecutivos; de ellos, 61 (8%) presentaron complicaciones mayores y 25 (3,3%) murieron. A partir de variables recogidas de forma prospectiva, se calcularon mediante un análisis de regresión logística los factores predictores para complicaciones mayores y mortalidad. En cada uno de los pacientes se calcularon las escalas de riesgo Parsonnet 95, Parsonnet 97, Euroscore, Cleveland, Ontario y Francesa. Mediante curvas ROC se comparó la capacidad de cada una de las escalas para predecir la mortalidad y la presencia de complicaciones mayores.

Resultados. En nuestra serie, las variables preoperatorias que aumentan significativamente el riesgo fueron: la resucitación cardiopulmonar, la presencia de insuficiencia renal, la arteriopatía periférica, la presencia de enfermedad coronaria severa de tronco izquierdo en más de 3 vasos y la fracción de eyección deprimida.

Conclusiones. Las escalas de riesgo que mejor predicen la mortalidad y la presencia de complicaciones mayores fueron Parsonnet 95 y Euroscore.

Palabras clave: *Revascularización. Factor de riesgo. Cirugía.*

INTRODUCTION

The analysis of results in coronary artery surgery has gained considerably in importance owing to the

high prevalence of interventions of this type with respect to cardiac surgery in general.

Coronary artery surgery without cardiopulmonary bypass (CPB) is a novel technique that reduces costs with respect to surgery involving CPB. This is due, among other reasons, to the fact that the procedure is less aggressive and, thus, the morbidity and mortality rates are lower,^{1,2} a circumstance that, in turn, reduces the utilization of health care resources.

The design of mortality prediction models for cardiac surgery is based on certain population groups, over a given period of time and taking into account specific preselected variables. Therefore, it seems logical to speculate on the possibility that the results of these studies could be applied to different populations at other points in time. There are several studies on factors predictive of mortality in the literature, including those carried out by Parsonnet et al,³⁻⁵ Grover et al,⁶ Hannan et al,⁷ O'Connor et al,⁸ Roques et al,⁹ Tu et al,¹⁰ and the Euroscore study group.¹¹ Others, in contrast, like those of Higgins et al,¹² Tuman et al,¹³ and Magovern et al,¹⁴ assess morbidity and mortality, and are more useful since they enable the identification of patients at risk for serious complications, which prolong the hospital stay and increase the use of resources. All of these models predictive of risk were designed on the basis of patients subjected to CPB. Thus, it is not known whether they can be applied in patients whose surgery does not involve that technique.

The objectives of this report are to identify preoperatively the risk factors that predispose this group of patients to develop major complications or die, and to validate, in our series of patients revascularized without CPB, 6 risk assessment tools utilized in patients subjected to CPB (Parsonnet 95, Parsonnet 97, Euroscore, Cleveland and Ontario scores, and a French scoring system).

PATIENTS AND METHODS

Patients

Between 1997 and 2002, an observational study involving the prospective follow-up of those patients who had undergone myocardial revascularization without CPB was carried out at Hospital Universitario Juan Canalejo in La Coruña, Spain. Patients who underwent some other cardiac surgical procedure associated with revascularization were excluded.

Myocardial revascularization was carried out through a median sternotomy in a group of 762 patients; we normally operate without the support of CPB (regardless of ventricular function or the quality of the surgical bed). In 85% of the patients, myocardial revascularization was performed using only the 2 internal mammary arteries. In our center, the usual

technique involves the utilization of these 2 vessels, skeletonized, as a T graft, and revascularization of anterior myocardium with left mammary artery; the lateral and inferior aspects are revascularized by means of side-to-side anastomoses using right mammary artery, avoiding aortic manipulation, an approach that was successful in 96% of the cases. Left internal mammary artery was employed in 99.5% of the procedures. On rare occasions, other vessels, such as radial artery, gastroepiploic artery and saphenous vein, were utilized to complete the revascularization. The mean number of anastomoses per patient was 2.7 ± 0.8 , and 3 or more coronary artery anastomoses were performed in 62% of the patients.

The mean age of the patients studied, 83.5% of whom were men, was 62.5 ± 9.5 years (range, 23 to 90 years). The preoperative risk factors most frequently identified were the presence of angina (95.8%), hypertension (58.4%), dyslipidemia (56.4%), and prior acute myocardial infarction (51.8%). The mean ejection fraction was $65.2 \pm 9.5\%$ (range, 23% to 88%). In the majority of the patients (80.5%), the ejection fraction was greater than 50% (Table 1).

Most of the patients (90.7%) underwent elective surgery, and the most common indication for surgery was three-vessel disease (50.3%), followed by left main coronary artery disease (25.6%). Preoperative intravenous nitroglycerin was required by 7.7% of the patients and 1.7% presented hemodynamic instability requiring inotropic support and/or preoperative intraaortic balloon pumping. The latter was placed in 18 patients, preoperatively in 7 (38.9%). The main indication for this measure was low cardiac output (76.5%) (Table 2). Twenty-five (3.3%) of the 762 patients studied have died and 61 (8.0%) developed major complications.

Methods

The following variables were assessed in all the study patients: age (in years); sex; hypertension (known history or systolic arterial pressure >140 mm Hg or diastolic arterial pressure >90 mm Hg on at least 2 occasions); dyslipidemia (known history, total cholesterol >200 mg/dL, low density lipoprotein cholesterol >130 mg/dL, high density lipoprotein cholesterol <30 mg/dL or triglycerides >150 mg/dL); current smoker (yes or no); diabetes (known history, regardless of the duration, with the exception of gestational diabetes); obesity; peripheral vascular disease (claudication of lower limbs during exercise or while at rest, or prior arterial revascularization of the aorto-ilio-femoral territory); carotid artery disease (symptomatic or asymptomatic with common or internal artery stenosis greater than 70% or previous endarterectomy); cardiomegaly; chronic obstructive pulmonary disease (COPD) (known history and treatment); family history of

TABLE 1. Distribution of the Patients According to Age, Sex, and Other Risk Factors*

Variable	Number	Percentage	95% CI
Men/women	636/126	83.5/16.5	80.6-85/14-19.49
Hypertension	445	58.4	54.8-61.9
Dyslipidemia	430	56.4	52.8-60
Current smoker	316	41.5	37.9-45.1
Diabetes	225	29.5	26.3-32.9
Obesity	121	15.9	13.4-18.7
Peripheral vascular disease	112	14.7	12.3-17.5
Carotid artery disease	37	4.9	3.5-6.7
Renal failure	31	4.1	2.8-5.8
Chronic obstructive pulmonary disease	62	8.1	6.3-10.4
Family history of angina/infarction	46	6	4.5-8
Preoperative dialysis	5	0.7	0.2-1.6
Heart failure	24	3.1	2.1-4.7
Cerebrovascular accident	12	1.6	0.9-2.8
Reoperation	7	0.9	0.4-2
Previous resuscitation	6	0.8	0.3-1.8
Stable/unstable angina	247/483	33.8/66.2	30.4-37.4/62.6-69.6
History of infarction	395	51.8	48.2-55.4
Ejection fraction >50%/<50%	610/148	80.5/19.4	77.4-83.2/16.2-23.7

Variable	Number	Mean±SD	Minimum/Maximum
Age	762	65.2±9.5	23/90
Ejection fraction	758	60.1±13.0	23/88
Left ventricular end-diastolic pressure	161	17.3±7.7	5/42

*CI indicates confidence interval; SD, standard deviation.

TABLE 2. Variables Related to the Surgical Treatment*

Variable	Number	Percentage	95% CI
Elective/delayed urgent/urgent/emergency	691/19/44/8	90.7/2.5/5.8/1	88.3-92.6/1.6-3.9/4.3-7.7/0.5-2.1
Left main coronary artery disease	195	25.6	22.6-28.9
One-vessel disease	46	6	4.5-8
Two-vessel disease	138	18.1	15.5-21.1
Three-vessel disease	383	50.3	46.7-53.9
Intravenous nitroglycerin	59	7.7	6-9.9
Hemodynamic instability	13	1.7	1-3
Balloon pumping	18	2.4	1.4-3.8

*CI indicates confidence interval.

coronary artery disease; renal failure (known history or most recent creatinine level >2 mg/dL); dialysis; pulmonary hypertension; heart failure (at the time of admission prior to surgery); associated valve lesion (prior valve replacement or repair); previous cerebrovascular accident (CVA, neurological deterioration with sequelae lasting at least 72 hours); prior cardiac intervention (surgical or percutaneous); preoperative cardiopulmonary resuscitation; other associated heart diseases; presence of angina; type of angina (stable [controlled with oral or transcutaneous medication] or unstable [angina at rest, recent onset angina induced by mild effort, effort-induced angina with recently lowered threshold, variant angina, nontransmural infarction within the preceding month or

angina requiring intravenous nitroglycerin, heparin sodium, low molecular weight heparin or balloon pumping); unstable angina requiring preoperative intravenous nitroglycerin, inotropic agents and/or balloon pumping; a history of acute myocardial infarction; ejection fraction; left ventricular end-diastolic pressure; type of surgery (emergency [with cardiopulmonary resuscitation on the way to the operating room or prior to anesthetic induction, acute ischemia, including angina at rest despite maximal medical treatment, myocardial infarction within the preceding 24 hours, acute pulmonary edema requiring orotracheal intubation, mechanical circulatory assistance, shock], urgent [requiring surgery within 24 hours to reverse a

TABLE 3. Variables Identified as Significant Predictors of Mortality in Logistic Regression Analysis*

Variables	β	SE	P	OR	95% CI
Ejection fraction	1.6	0.45	.000	4.9	2-11.9
Renal failure	2.35	0.56	.000	10.5	3.5-31.1
Arterial disease	1.66	0.47	.000	5.3	2.1-13.1
Resuscitation	2.38	0.1	.016	10.8	1.55-74.9
Main coronary artery and three-vessel disease	1.46	0.5	.003	4.3	1.65-11.2
Constant	-5.23	0.46	.000	0.005	-

* β indicates beta coefficient; CI, confidence interval; OR, odds ratio; SE, standard error of β .

deterioration in the clinical condition due to myocardial infarction, unstable angina at rest or angina requiring nitroglycerin or balloon pumping], delayed [similar to urgent, but scheduled to be performed during the current hospital stay] and elective [a scheduled intervention that is neither delayed, urgent nor emergency surgery]); and number of coronary vessels involved.

The preoperative characteristics of each patient were used to calculate their risk according to the Parsonnet 95, Parsonnet 97, Euroscore, Cleveland, Ontario, and French scoring systems.

The postoperative variables analyzed in our study were whether or not the patient died and whether or not he or she developed major complications.

– Mortality was defined as deaths occurring during the hospital stay in which the operation was performed, regardless of the length of the stay, or within 30 days of the surgical intervention.

– The complications considered to represent major morbidity were events such as perioperative infarction, low output requiring intraaortic balloon pumping and/or mechanical ventilation, major arrhythmia (ventricular fibrillation or complete atrioventricular block), respiratory complications and those requiring mechanical ventilation for over 48 hours, focal neurological lesions confirmed on the basis of the clinical features and/or computed tomography, diffuse encephalopathy lasting over 24 hours and requiring mechanical ventilation or accompanied by a severely impaired mental status, renal failure requiring ultrafiltration or dialysis, mediastinitis and generalized sepsis. The groups in which these complications developed include the patients who died as all of them presented at least one.

Statistical Analysis

The quantitative variables were expressed as the mean plus or minus the standard deviation. The qualitative variables were expressed as absolute value and percentage, with the 95% confidence interval.

The comparison of the means was performed using the Mann-Whitney test and, once the normal distribution

of the variables had been established, the Kolmogorov-Smirnov test. The chi-squared test was employed for the comparison of the qualitative values. To identify the variables predictive of events of interest, we performed a logistic regression analysis in which the variables of interest (mortality and major complications) were used as dependent variables and, as covariables, those that univariate analysis showed to be associated with said variables or that were clinically or surgically relevant. The variables predictive of mortality and major complications were identified using logistic regression models.

The comparison of the different scoring systems for predicting mortality and major morbidity was carried out by means of receiver operating characteristic (ROC) curves.

RESULTS

The covariables that had been found to be significantly associated with mortality in the univariate analysis were subsequently evaluated by logistic regression analysis. Taking into account patient age, ejection fraction, preoperative renal failure, previous CVA, COPD, peripheral arterial disease, carotid artery disease, prior cardiopulmonary resuscitation, valve lesion, emergency surgery, main coronary artery disease plus three-vessel disease, preoperative intravenous nitroglycerin, and preoperative hemodynamic instability, we observed that those that significantly modified the risk of death were previous cardiopulmonary resuscitation (odds ratio [OR], 10.8), the presence of preoperative renal failure (OR, 10.5), peripheral arterial disease (OR, 5.3), main coronary artery disease plus three-vessel disease with significant stenoses (OR, 4.3) and the ejection fraction (OR, 4.9) (Table 3).

The covariables that had been found to be significantly associated with major complications in the univariate analysis were subsequently evaluated by logistic regression analysis. Taking into account the variables age, ejection fraction, preoperative renal failure, previous CVA, peripheral arterial disease, carotid artery disease, previous cardiopulmonary resuscitation, valve lesion, type of surgery, left main

TABLE 4. Variables Identified as Significant Predictors of Major Complications in Logistic Regression Analysis*

Variables	β	SE	P	OR	95% CI
Ejection fraction	1.21	0.3	.000	3.4	1.9-6
Renal failure	1.26	0.49	.010	3.5	1.4-9.1
Arterial disease	1.4	0.3	.000	3.9	2.1-7.4
Resuscitation	3.1	1.0	.001	21.4	3.4-136.6
Main coronary artery and three-vessel disease	0.75	0.4	.041	2.1	1.03-4.3
Cerebrovascular accident	1.6	0.8	.049	4.9	1.02-24.2
Hemodynamic instability	1.8	0.67	.006	6.2	1.7-22.7
Constant	-3.56	0.24	.000	-	-

* β indicates beta coefficient; CI, confidence interval; OR, odds ratio; SE, standard error of β .

coronary artery disease plus significant lesions in the 3 coronary vessels, previous heart failure, and preoperative hemodynamic instability, it was observed that the variables that significantly modified the risk of major complications were renal failure (OR, 3.5), peripheral arterial disease (OR, 3.9), cardiopulmonary resuscitation (OR, 21.4), left main coronary artery disease plus significant lesions in the 3 coronary vessels (OR, 2.1), history of CVA with sequelae (OR, 4.9), hemodynamic instability (OR, 6.2), and the ejection fraction (OR, 3.4) (Table 4). The capacity of the different scoring systems to predict mortality is shown in Figure 1. The tool that best predicted mortality in our series was Parsonnet 95, with an area under the curve of 90%, followed by the Euroscore, with an area under the curve of 86% and Parsonnet 97, with an area under the curve of 82%. The French scoring system exhibited the poorest capacity to predict mortality in our series, with an area under the curve of 55%. When we indicate that the area under the curve of the Parsonnet 95 score for the prediction of mortality is 90%, it means that if we apply the Parsonnet 95 score to randomly selected living and deceased patients, 90% of those who die present a higher value.

The diagnostic capacity for predicting the development of major complications appears in Figure 2. Again, the tool that best predicted major complications in our series was Parsonnet 95, with an area under the curve of 74.1%, followed by the Euroscore, with an area under the curve of 74%, and Parsonnet 97, with an area under the curve of 72%. The French scoring system was that with the poorest capacity for the prediction of major complications in our series, with an area under the curve of 57%.

DISCUSSION

On the basis of a cooperative study involving several North American states, in which the authors identified the preoperative variables necessary for risk adjustment of death in coronary artery bypass graft surgery,¹⁵ we selected the variables used to determine

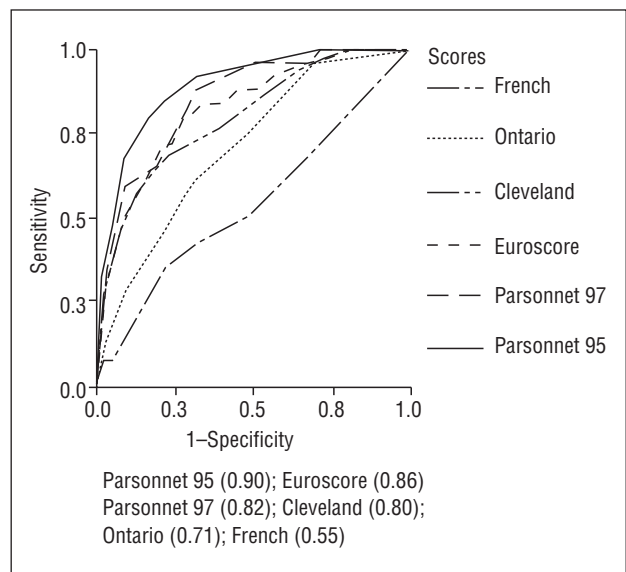


Figure 1. Receiver operating characteristic (ROC) curves comparing the ability of the different risk assessment tools to predict mortality.

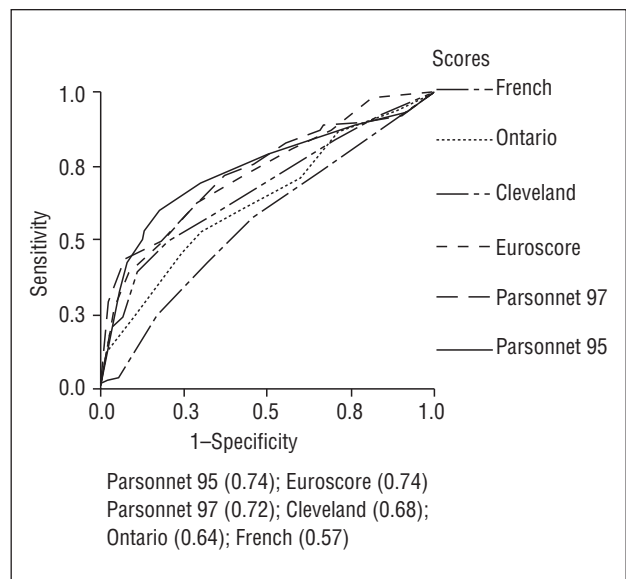


Figure 2. Receiver operating characteristic (ROC) curves comparing the ability of the different risk assessment tools to predict major complications.

the preoperative risk factors predictive of mortality and major complications in our patients, which are shown in Tables 1 and 2.

Most studies of the factors predictive of mortality using logistic regression models are carried out in patients undergoing surgery with CPB.^{10,12} If we review some of the studies involving surgical patients in whom CPB was not performed, we observe that Buffolo et al¹⁶ found statistical significance in the preoperative angina class and age over 70 years, and Moshkovitz et al¹⁷ presented as significant variables functional class IV angina, emergency surgery and aortic calcification. Riha et al¹⁸ reported the statistical significance of age, female sex, functional class IV angina, hypertension, hypercholesterolemia, previous CVA, and preoperative renal failure. All these studies were based on univariate analysis, in which each variable was analyzed independently with regard to living and deceased patients.

In a study published by Mack et al¹⁹ involving 1915 surgical patients in whom CPB was not performed, multivariate logistic regression analysis identified age, female sex, and preoperative renal failure as variables significantly associated with death. These results agree with those of our study in recognizing preoperative renal failure as a risk factor, but we observed no significant association with age or sex. There were no deaths among our female patients or individuals in their eighties, a fact that may be related to the systematic use of both mammary arteries, regardless of the age or sex of the patient, and to the extensive experience of our surgical team in procedures of this type.

When this logistic regression analysis was carried out using the development of major complications as the dependent variable, we observed that the same variables, plus previous CVA with sequelae and preoperative hemodynamic instability, showed statistical significance. The patients who required preoperative cardiopulmonary resuscitation, although very few, presented a highly significant association with the occurrence of major complications or mortality (Table 4).

When these findings are compared with studies of morbidity and mortality in which the criteria applied were similar to ours but in patients undergoing cardiac surgery with CPB, we observe that Higgins et al¹² studied 27 risk factors, 11 of which proved to be significant according to logistic regression analysis. Preoperative renal failure, peripheral arterial disease, left ventricular dysfunction, previous CVA, and the degree of urgency of the operation (when previous cardiopulmonary resuscitation and preoperative hemodynamic stability are included in the definition) were also identified in our study. In a similar report, Tuman et al¹⁷ studied 17 risk factors and found statistical significance in 11 of them. As in our

work, preoperative renal failure, previous CVA, left ventricular dysfunction and, by definition, the degree of urgency of the intervention proved to be predictive of morbidity and mortality. We specify "by definition" since, in both studies, the emergency surgery group includes those patients who required previous cardiopulmonary resuscitation and those who presented hemodynamic instability requiring inotropic support and/or preoperative balloon pumping. Other factors predictive of morbidity and mortality were age, myocardial infarction within the preceding 6 months, reoperation, female sex, pulmonary hypertension, and congestive heart failure. Peripheral arterial disease was not included among the preoperative risk factors in that study. The same risk factors were found to be predictive of morbidity and mortality by Magovern et al¹⁴ in their study.

Left main coronary artery disease with significant lesions in the three coronary vessels, which reached statistical significance in our study, was not analyzed as a risk factor by Tuman et al, while Higgins et al included it, defining the variable as coronary artery lesion involving more than 50%; thus, its value was reduced by dispersion among the entire patient group. Nevertheless, the predictive value of left main coronary artery disease in terms of morbidity and mortality is completely accepted. In a consensus study designed to create a database project, it was included among the essential variables in view of its unquestionable predictive value.¹⁵

We were unable to find reports on preoperative factors predictive of morbidity and mortality in patients who undergo coronary artery surgery without CPB, but studies focusing on the associated mortality^{19,20} do not identify as risk factors predictive of mortality variables that were found to be significant by Higgins et al¹², Tuman et al,¹³ and Magovern et al¹⁴ (reoperation, mitral insufficiency, weight under 65 kg, hematocrit <34%, diabetes, COPD, aortic stenosis, and infarction within the previous 6 months).

In our study, four risk assessment tools presented ROC curves with areas under the curve equal to or greater than 0.80, results that demonstrate their excellent discriminatory capacity (Figure 1) and, thus, the efficacy of the model as a predictor of mortality in our series; these results are even more significant than those of other authors who, using some of these risk scores, obtained areas under the curve indicative of the good performance of the models, but exhibiting lower values than ours.²¹⁻²³

The analysis of the major complications revealed that the Parsonnet 95 and Euroscore scores show the best discriminatory ability, with areas under the curve of 0.74 (Figure 2). These scoring systems, which were constructed for use in mortality, were those that best estimated the risk of major complications in our series of patients. In contrast, despite the fact that the

Cleveland score was designed for use with morbidity and mortality, and our meeting its criteria for the collection of data concerning the dependent variable (major complications), the resulting area under the curve was 0.68, which is acceptable, but inferior to that of Parsonnet 95 and 97 and the Euroscore. This demonstrates that mortality scoring systems may be valid in samples in which the dependent variable is major complications.

Higgins et al¹² and Tuman et al¹³ constructed their morbidity and mortality scores on the basis of the variables that proved significant in the logistic regression analyses of mortality and major morbidity. The subsequent validation of these scoring systems revealed a correspondence between the expected and observed mortality and morbidity. Orr et al²² reported results similar to ours, but used only mortality as the dependent variable, with an area under the curve of 0.74 according to the Parsonnet score and of 0.72 with the Cleveland score. Other authors demonstrate discriminating powers of these models even greater than ours, with an area under the curve of 0.83 with the Parsonnet score, 0.82 with the Euroscore and 0.82 with the Cleveland score.²¹

CONCLUSION

Knowledge of the preoperative factors predictive of mortality and major complications will enable us to identify those patients at greater risk and adopt appropriate management strategies, as well as additional measures that may be necessary, both in organizational terms and with regard to resources, with the ultimate objective of reducing the presence of adverse events. Moreover, knowledge of our own preoperative factors predictive of mortality will enable us to eliminate the limitations to treatment efficacy, to quality of care and to the use of the available resources associated with the utilization, to evaluate our results, of preoperative predictive factors derived from studies carried out in other patient populations, with different demographics.²⁰

We also wish to point out the fact that, with the exception of the French scoring system, the mortality and the morbidity and mortality scores analyzed in our study, which were designed on the basis of data from patients subjected to surgery involving CPB, can also be utilized to predict the risk of death and of major complications in patients undergoing myocardial revascularization without CPB. The Parsonnet 95 score and the Euroscore were those that best predicted the final results, and both are highly useful in coronary artery surgery with and without CPB.²⁴ This is a novel technique for which, to date, no risk assessment scores have been constructed on the basis of the preoperative characteristics of the patients involved.

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