Original Article

A First Postoperative Day Predictive Score of Mortality for Cardiac Surgery

Renato Vieira Gomes, MD,[1,2] Bernardo Tura, MD,[2]
Hugo Tannus Furtado de Mendonça Filho, MD, PhD,[1]
Luis Antonio de Almeida Campos, MD,[1,2] Alexandre Rouge, MD,[1,2]
Pedro Miguel de Matos Nogueira, MD,[1] Marco Aurélio de Oliveira Fernandes, MD,[1]
Hans Fernando da Rocha Dohmann, MD,[1] and Ademir Batista Cunha, MD, PhD[2,3]

Purpose: Several prognostic scores for cardiac surgery based on preoperative variables are available. We propose a new one based on pre- and intraoperative and first postoperative day variables for cardiac surgery patients admitted to a surgical intensive care unit.

Materials and Methods: Classical cohort of data consecutively collected from June 2000 to March 2003 (1,458 patients). Forty-six risk variables were identified. The statistical study comprised univariate analysis followed by logistic regression with receiver operating characteristics (ROC) curve.

Results: After logistic regression, the selected variables and respective odds ratios were: age >65 and <75 years (2.05); age ≥75 years (4.79); left atrial diameter >45 mm (2.58); preoperative creatinine >2 mg/dL (4.84); and cardiopulmonary bypass time ≥180 min (4.93±2). The first postoperative day variables were as follows: the worst PaO_2/FiO_2 <100 (9.47); epinephrine or norepinephrine dose ≥0.1 μg/kg/min (6.78); and mechanical ventilation time >12 h (2.24). The area under the ROC curve was 0.84.

Conclusion: The score shows the strength of first postoperative day variables, probably related to intraoperative conditions. It also evidences the importance of left atrial diameter as a new marker of preoperative risk. (Ann Thorac Cardiovasc Surg 2007; 13: 159–164)

Key words: cardiac surgery, prognosis, postoperative period, death

Introduction

Most prognostic scores available in the literature[1–5] are based on preoperative variables and were validated in the populations which were studied. Evidence exists that isolated or combined tissue perfusion alterations may interfere with the blood levels of some mediators (cytokines, free oxygen radicals) and may be related to greater postoperative morbidity.[6–9] Therefore, intraoperative and immediate postoperative variables may interfere with the occurrence of organic dysfunction, thus impairing surgical prognosis.

The oldest and most largely used risk score in intensive care is the Acute Physiology and Chronic Health Evaluation (APACHE),[10] whichwas revised in 1985 and named APACHE II.[11] One study,[12] analyzing prognostic difficulties in cardiac surgery (CS), assessed the impact of the combination of the preoperative variables of the Parsonnet score,[1] intraoperative variables [cardiopulmonary bypass (CPB) time and cross-clamping time], and postoperative variables (APACHE II and APACHE III)[13] on CS to predict mortality and surgical intensive care unit length of stay. That study reported a real mortality of 2.7%

From [1]Surgical Intensive Care Unit, Hospital Pró-Cardíaco, [2]Surgical Intensive Care Unit, Instituto Nacional de Cardiologia Laranjeiras, and [3]Department of Cardiology, Hospital Antônio Pedro of the Fluminense Federal University, Rio de Janeiro, Brazil

Received June 27, 2006; accepted for publication September 11, 2006

Address reprint requests to Renato Vieira Gomes, MD: Surgical Intensive Care Unit MSc. Hospital Pró-Cardíaco, Rua General Polidoro 192, Botafogo, Rio de Janeiro, RJ, ZIP: 22280-000, Brazil.

in surgical intensive care unit (SICU) and an in-hospital mortality of 3.8%. The mortality predicted through the APACHE II was 5.31%, yielding a standardized mortality rate of 0.71 for the SICU. This could indicate the good quality of the care provided at the intensive care unit or a failure of the APACHE II to predict mortality related to CS. Applying a logistic regression to that cohort to analyze CPB time, need for inotropic agents, mean blood pressure, urea levels, and the Glasgow coma scale, the resulting model reached the greatest area under the receiver operating characteristics (ROC) curve (0.87), which was 0.82 in the Parsonnet model and 0.84 in the APACHE II model. The study by Whiteley et al.[14] adds up new physiological variables of the immediate postoperative period to the preoperative score of Higgins,[5] creating a model with an area under the ROC curve of 0.87 to predict mortality and of 0.82 to predict morbidity. Those findings stress the use of intra- and postoperative variables to predict outcome. Therefore, we created a score to predict in-hospital mortality in CS on the first postoperative day (FPOD) by using pre-, intraoperative, and FPOD variables.

Materials and Methods

This cohort comprised data from all 1,458 patients consecutively admitted and stored in databases at the SICUs of the following two hospitals: Hospital Pró-Cardíaco and Instituto Nacional de Cardiologia Laranjeiras, from June 2000 to March 2003. The following preoperative variables were assessed: age, sex, previous acute myocardial infarction (Q-wave infarction within the preceding 3 months), severe left ventricular dysfunction (left ventricular ejection fraction lower than or equal to 30%), left atrial diameter (LAD), diabetes, creatinine, body mass index (BMI), emergency surgery (surgery necessity in the first 24 h of hospitalization), previous CS, previous atrial fibrillation (intermittent or sustained), unstable angina, pulmonary hypertension (systolic pulmonary pressure higher than 60 mmHg), peripheral vascular disease (any arterial lesion higher than or equal to 60% on Doppler echography, intermittent claudication or aortic aneurysm) and active endocarditis. The intraoperative variables assessed were as follows: CPB time, intraoperative fluid imbalance index, intraoperative blood component use, alveoloarterial oxygen tension gradient, and arterial bicarbonate at the end of the procedure. The FPOD variables were as follows: PaO_2/FiO_2 ratio, dobutamine and norepinephrine dose, mechanical ventilation (MV) time, platelet count, and creatinine. Those variables were assessed in regard to their impact on death at any time of hospitalization and previously defined as in the following prognostic scores: ACC/AHA,[4] EuroSCORE,[3] Cleveland,[5] multiple organ dysfunction score (MODS),[15] and sepsis-related organ failure assessment (SOFA).[16] All numerical variables were transformed into categorical as in most prognostic scores available in the literature.

The written informed consent was not required by the institutional review board, because the study was a database analysis and the author signed a term of commitment regarding the confidentiality of the patients' identities.

The statistical analysis was performed with the Statistica 6.0 software. A significance level of 95% and power of 80% were adopted.

The statistical treatment comprised the chi-square test and multiple logistic regression (LR). The first analysis used only preoperative variables and selected those with a greater impact on in-hospital mortality. In the second analysis, intraoperative variables were added up and another LR was performed, selecting again the variables with the greatest impact on in-hospital mortality. Finally, the postoperative variables were added up to the result of the last regression, and a new LR was carried out. The variables were selected through forward and backward stepwise, by using the likelihood ratio. The specificity and sensitivity of the model were measured by use of the ROC curve.

Results

After univariate analysis, the variables were selected to undergo multivariate analysis. This model selected eight preoperative variables with their respective significance levels and odds ratio (OR) (Table 1). Then, the intraoperative variables were added up to the eight significant preoperative variables selected (Table 1). These variables underwent a new LR that selected ten independent and significant variables with impact on the outcome (Table 2). Finally, the first postoperative day variables were added up to those ten significant and independent variables. These variables were submitted to a new LR that selected eight independent variables. After analyzing the OR, the death distribution and the prevalence of the variables selected in successive LRs, the score was created (Table 3).

The score showed good sensitivity and specificity with an area under the ROC curve of 0.84 (Fig. 1). This finding emphasizes the importance of the inclusion of post-

Table 1. Result of the logistic regression with preoperative variables

Variable	Beta	P value	OR	Confidence interval
Age >65 and <75 years	0.6999	0.0153	2.0136	1.437–3.542
Age ≥75	1.5356	0.0000	4.6441	2.6897–8.4070
LAD >45 mm	0.9514	0.0003	2.5893	1.5467–4.33346
Creatinine >2 mg/dL	1.8740	0.0000	6.5144	2.6897–15.7775
BMI <20	0.5052	0.0507	1.6573	0.9985–2.7508
Emergency CS	0.9271	0.0057	2.5271	1.3095–4.8769
PVD	0.7101	0.0056	2.0342	1.2303–3.3632
Active endocarditis	1.2895	0.0229	3.6310	1.1959–11.0240

LAD, left atrial diameter; BMI, body mass index; CS, cardiac surgery; PVD, peripheral vascular disease; OR, odds ratio.

Table 2. Result of the logistic regression with pre- and intraoperative variables

Variables	Beta	P value	OR	Confidence interval
Age >65 and <75 years	0.6717	0.0186	1.9576	1.1187–3.4258
Age ≥75	1.5483	0.0000	4.7036	2.5869–8.5522
LAD >45 mm	0.8628	0.0011	2.3698	1.4142–3.9709
Creatinine >2 mg/dL	1.8643	0.0000	6.4515	2.6897–5.7775
Emergency CS	0.8076	0.0194	2.2426	1.1392–4.4146
PVD	0.6178	0.0169	1.8549	1.1175–3.0789
Active endocarditis	1.1831	0.0463	3.2646	1.0196–10.4528
CPB time ≥120 <180 min	0.5647	0.0391	1.7588	1.0286–9.71837
CPB time ≥180 min	1.2764	0.0127	4.9326	1.9970–12.137
Alveoloarterial oxygen tension gradient >250	0.6907	0.0087	1.19951	1.1912–3.3417

LAD, left atrial diameter; CS, cardiac surgery; PVD, peripheral vascular disease; CPB, cardiopulmonary bypass; OR, odds ratio.

Table 3. Prediction of in-hospital death on the FPOD

Variable	Beta	P value	OR	Confidence interval	Points
Age >65 and <75 years	0.7198	0.0132	2.0541	1.1621–3.6307	+1
Age ≥75 years	1.5678	0.0000	4.7960	2.6024–8.8387	+2
LAD >45 mm	0.9511	0.0004	2.5885	1.5331–4.3706	+1
Creatinine >2 mg/dL	1.5778	0.0011	4.8443	1.8792–12.4878	+2
CPB time ≥180 min	1.5959	0.0005	4.9326	1.9970–12.1837	+2
PaO_2/FiO_2 <100	2.2489	0.0001	9.4775	3.1818–28.2309	+3
Epinephrine or norepinephrine ≥0.1 μg/kg/min	1.9147	0.0000	6.7848	3.9916–11.5326	+3
MV time >12 h	0.8066	0.0019	2.2402	1.3479–3.7233	+1

FPOD, first postoperative day; LAD, left atrial diameter; CPB, cardiopulmonary bypass; MV, mechanical ventilation; OR, odds ratio.

operative variables in the prognostic assessment of CS.

After analyzing the mortality distribution by use of cross-tabulation, our score was divided into the following prediction ranges of in-hospital death risk:

• Low risk: score from 0 to 2, with a predicted mortality of 3.5%;

• Medium risk: score from 3 to 5, with a predicted mortality of 7.5%;

• High risk: score ≥6, with a predicted mortality >15%.

With the aim of the sensitivity and specificity of other prognostic models of in-hospital death in our cohort, we built ROC curves using the postoperative Cleveland score (Fig. 2) and the SOFA score of the FPOD (Fig. 3).

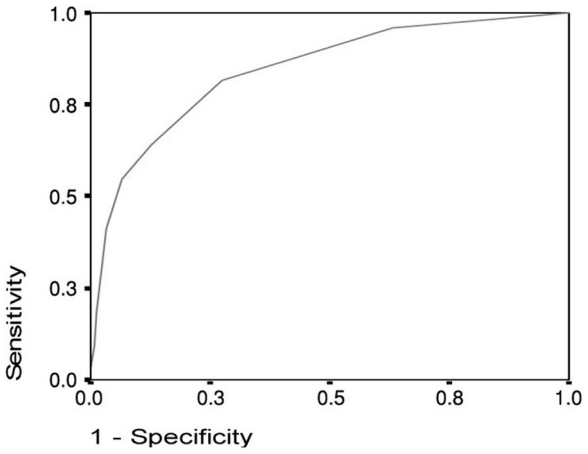

Fig. 1. Receiver operating characteristics (ROC) curve of our score with an area under the curve of 0.84.

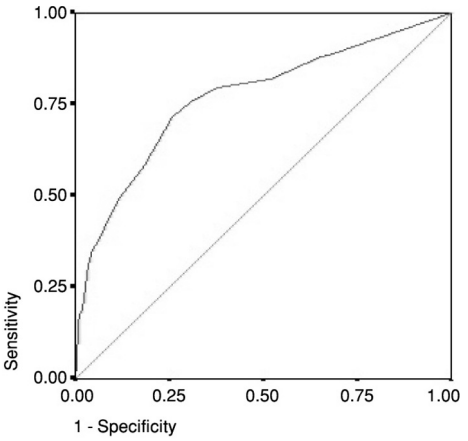

Fig. 2. Receiver operating characteristics (ROC) curve of the postoperative Cleveland score (area under the curve of 0.769).

Discussion

Improvement in the quality of care provided to patients seems to be the major objective of risk stratification, justifying the existence of several assessment systems.[1,3,5,17)]

The medicine, angioplasty, or surgery study II,[18)] which compared coronary artery bypass grafting, percutaneous transluminal coronary angioplasty and clinical treatment in Brazil, reported an in-hospital mortality of 2.5% at the Instituto do Coração in São Paulo, which is high when compared to that predicted by international risk scores (Euroscore and American Heart <1%). When adjusted to our risk patterns (our score=2), a mortality of up to 3.5% could be expected. These data emphasize the need for creating a score that may reflect the reality of a developing country.

In the literature, there are some references to LAD measurement on echocardiography as a risk marker in CS. Ogendo[19)] studied the 30-day mortality in 563 patients undergoing open heart surgery at the Kenyatta National Hospital. Only cross-clamping time longer than 60 min and LAD >5 cm were independent risk markers after LR. Vural[20)] analyzed the results of ventriculectomy and mitral valve replacement aiming to treat idiopathic dilated cardiomyopathy. The independent predictors of mortality were as follows: end-diastolic pressure >25 mmHg, LAD >55 mm, systolic pulmonary artery pressure >40 mmHg, congestive hepatomegaly, and New York Heart Association class IV. Reed et al.[21)] studied 176 patients undergoing mitral valve replacement due to insufficiency and selected clinical, laboratory, echocardiographic and hemodynamic variables to predict cardiovascular death. The following variables were significant: preoperative bubbling rales, LAD, and the left ventricle shortening rate on echocardiography (P<0.0001).

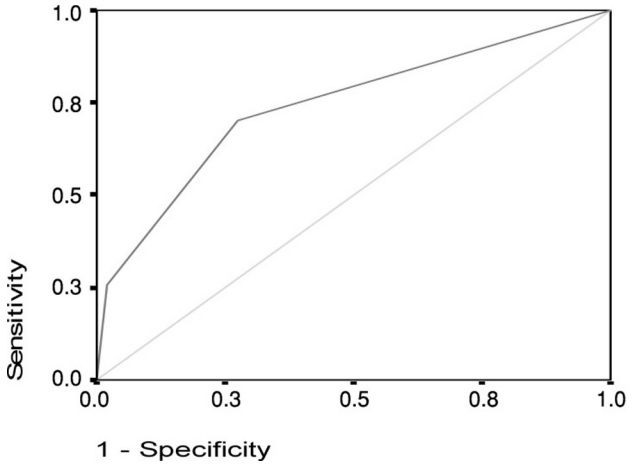

Fig. 3. Receiver operating characteristics (ROC) curve of the sepsis-related organ failure assessment (SOFA) score of the first postoperative day (area under the curve of 0.74).

The LAD impact on in-hospital mortality found in our score may reflect high levels of atrial natriuretic peptide in patients with previous diastolic dysfunction. In those with valvular insufficiency, it seems to be a better marker in the absence of systolic dysfunction. Although it has been neither largely used nor prospectively validated, it seems to be very promising to continue studying LAD.

After LR, our score showed significance for CPB time ≥180 min (P=0.0127), as reported by Turner et al.[12)]

The FPOD variables were the initial focus of our study.

Although it is clear that adverse postoperative evolution is related to preoperative risk factors and intraoperative and postoperative clinical/surgical management, this interaction needs to be quantified.

Kuhn et al.[22] studied the APACHE II of the FPOD of patients undergoing CS, except for transplantation, and reported the following: mortality increased almost 50% for an APACHE II of 28; a high risk of systemic inflammatory response with an APACHE II of 24; patients with an APACHE II <19 had shorter mechanical ventilation and CPB times, were younger, and their New York Heart Association classification was lower. The simplest SOFA and MODS scores, which use few variables of simple definition, measure organic dysfunction and may be used in intensive care unit admission and evolution. Vincent et al.[23] believes that the scores of organic dysfunction are better for follow-up assessment. When the FPOD SOFA score was applied to our cohort, the area under the ROC curve was 0.783 (Fig. 2), lower than that obtained with our score (0.84), but greater than that obtained with the postoperative Cleveland score (0.769) (Fig. 3). Those findings are similar to those of Turner et al.[24] and Whiteley et al.,[14] who created a prediction model with variables of the APACHE II.

The PaO_2 to FiO_2 ratio is widely used to measure pulmonary dysfunction in several prognostic models, such as SOFA, MODS, simplified acute physiology score II,[25] logistic organ dysfunction system,[26] being, therefore, already validated. The use of amines as a risk marker in a prognostic model for CS was reported by Edward et al.[2] The use of amine level as a cardiovascular dysfunction marker has been spread by Vincent et al.[23] with the SOFA score aiming at facilitating cardiovascular dysfunction measurement. Gonçalves et al.[27] studied the possibility of deleterious effects with the use of NE in critically-ill surgical patients and observed that a high MODS score was an independent marker of the use of NE for death, and that the group using NE had a higher MODS score even without considering cardiovascular dysfunction ($P<0.001$). After multivariate analysis, the MODS ($P<0.0001$) and APACHE III ($P<0.01$) scores were independent markers of mortality. Mechanical ventilation time was also studied by Leal-Noval et al.,[28] who showed the impact of early extubation on the reduction of in-hospital pneumonia. Some studies[28,29] showed the impact of MV time on the postoperative period of CS and the increase in infection and lethality.

Limitations

The major limitation of our study was the lack of prospective validation of the model; however, we believe in its predictive power because we do not have another risk score validated within our milieu, and our score has a greater area under the ROC curve (0.84) than that of the postoperative Cleveland score (0.769).

Conclusions

Advanced age and renal dysfunction are independent risk markers in CS. The prognostic model presented showed the importance of LAD >45 mm as an independent marker of in-hospital death in CS patients. Prolonged CPB time (≥180 min) proved to be a marker of worse prognosis among us. The FPOD variables, such as the worst PO_2/FiO_2 <100, epinephrine or norepinephrine ≥0.1 μg/kg/min, and MV time >12 h, have a great impact on mortality.

The model created, although not prospectively validated, has easily-defined and widely-used variables in CS and intensive care, and may be easily used.

References

1. Parsonnet V, Dean D, Bernstein AD. A method of uniform stratification of risk for evaluating the result of surgery in acquired adult heart disease. *Circulation* 1989; **79** (6 Pt 2): I3–12.
2. Edwards FH, Clark RE, Schwartz M. Coronary artery bypass grafting: the Society of Thoracic Surgeons National Database experience. *Ann Thorac Surg* 1994; **57**: 12–9.
3. Nashef SA, Roques F, Michel P, et al. European System for cardiac operative risk evaluation (EuroSCORE). *Eur J Cardiothorac Surg* 1999; **16**: 9–13.
4. Eagle KA, Guyton RA, Davidoff R, et al. ACC/AHA Guideline for Coronary Artery Bypass Graft Surgery: executive summary and recommendations (Committee to Revise the 1991 Guidelines for Coronary Artery Bypass Graft Surgery). *Circulation* 1999; **100**: 1464–80.
5. Higgins TL, Estafanous FG, Loop FD, et al. Stratification of morbidity and mortality outcome by preoperative risk factors in coronary artery bypass patients. A clinical severity score. *J Am Med Assoc* 1992; **267**: 2344–8.
6. Cremer J, Martin M, Redl H, et al. Systemic inflammatory response syndrome after cardiac operations. *Ann Thorac Surg* 1996; **61**: 1714–20.
7. Stoica SC, Sharples LD, Ahmed I, et al. Preoperative risk prediction and intraoperative events in cardiac sur-

gery. *Eur J Cardiothorac Surg* 2002; **21**: 41–6.
8. Fransen E, Maessen J, Dentner M, et al. Systemic inflammation present in patients undergoing CABG without extracorporeal circulation. *Chest* 1998; **113**: 11–22.
9. Mendonça-Filho H, Gomes RV, Campos LAA, et al. Macrophage migration factor. C reactive protein and C3a serum levels following CABG. *C C Forum* 2001; **5**: P21.
10. Knaus W, Zimmerman JE, Lawrence DE, et al. APACHE-acute physiology and chronic health evaluation: a physiologically based classification system. *Crit Care Med* 1981; **9**: 591–7.
11. Knaus W, Draper EA, Wagner DP, et al. APACHE II: a severity of disease classification system. *Crit Care Med* 1985; **13**: 818–29.
12. Turner J, Morgan CJ, Pepper JR, et al. Difficulties in predicting outcome in cardiac surgery patients. *Crit Care Med* 1995; **23**: 1843–50.
13. Knaus W, Wagner DP, Damiano A, et al. The APACHE III prognostic system. Risk prediction of hospital mortality for critically ill hospitalized adults. *Chest* 1992; **102**: 1919–20.
14. Whiteley MS, Prytherch DR, Higgins B, et al. Prout, W.G. P-POSSUM out-performs POSSUM in predicting morbidity in surgical patients. *Br J Surg* 1997; **84**: 51–2.
15. Marshall J, Cook DJ, Sibbald WJ, et al. Multiple organ dysfunction score: a reliable descriptor of a complex clinical outcome. *Crit Care Med* 1995; **23**: 1638–52.
16. Vincent JL, Moreno R, Takala J, et al. The SOFA (sepsis-related organ failure assessment) score to describe organ dysfunction/failure. *Intensive Care Med* 1996; **22**: 707–10.
17. Parsonnet V, Dean D, Bernstein AD. A method of uniform stratification of risk for evaluating the result of surgery in acquired adult heart disease. *Circulation* 1989; **79**: I3–II2.
18. Hueb W, Soares PR, et al. The medicine, angioplasty, or surgery study (MASS-II): a randomized, controlled clinical trial of three therapeutic strategies for multivessel coronary artery disease one-year results. *J Am Coll Cardiol* 2004; **43**: 1743–51.
19. Ogendo S. Thirty day mortality and related variables in open heart patients at the Kenyatta National Hospital, Nairobi. *East Afr Med J* 2001; **78**: 526–30.
20. Vural K, Tasdemir O. Mid-term results of partial left ventriculectomy in end-stage heart disease. *Eur J Cardiothorac Surg* 2000;**18**: 550–6.
21. Reed D, Abbott RD, Kaul S, et al. Prediction of outcome after mitral valve replacement in patients with symptomatic chronic mitral regurgitation: The importance of left atrial size. *Circulation* 1991; **84**: 23–34.
22. Kuhn C, Müller-Werdan U, Schmitt DV, et al. Improved outcome of APACHE II score-defined escalating systemic inflammatory response syndrome in patients post cardiac surgery in 1996 compared to 1988–1990: the ESSICS-study pilot project. *Eur J Cardiothorac Surg* 2000; **17**: 30–7.
23. Vincent J, Ferreira F, Moreno R, et al. Scoring systems for assessing organ dysfunction and survival. *Crit Care Clin* 2000; **16**: 353–66.
24. Turner JS Morqan CJ, Thakrar B, et al. Difficulties in predicting outcome in cardiac surgery patients. *Crit Care Med* 1995; **23**: 1843–50.
25. Le Gall J, Lemeshow S, Saulnier F. A new simplified acute physiology score (SAPS II) based on a European/North American multicenter study. *JAMA* 1994; **271**: 1321.
26. Le Gall J, Klar J, Teres D. The logistic organ dysfunction system. a new way to assess organ dysfunction in the intensive care unit. ICU Scoring Group. *JAMA* 1996; **276**: 802–10.
27. Gonçalves J, Hydo LJ, Barie PS, et al. Factors influencing outcome of prolonged norepinephrine therapy for shock in critical surgical illness. *Shock* 1998; **10**: 231–6.
28. Leal-Noval S, Marquez-Vácaro JA, García-Curiel A, et al. Nosocomial pneumonia in patients undergoing heart surgery. *Crit Care Med* 2000; **28**: 935–40.
29. Fransen E, Maessen J, Dentener M, et al. Impact of blood transfusions on inflammatory mediator release in patients undergoing cardiac surgery. *Chest* 1999; **116**: 1233–9.