Published in final edited form as:

Ann Thorac Surg. 2010 August ; 90(2): 522–526. doi:10.1016/j.athoracsur.2010.04.035.

A Clinical Score to Predict the Need for Intraaortic Balloon Pump in Patients Undergoing Coronary Artery Bypass Grafting

Antonio Miceli, MD, Simon M. J. Duggan, MD, Radek Capoun, MD, Francesco Romeo, MD, Massimo Caputo, MD, and Gianni D. Angelini, MD, FRCS

The Bristol Heart Institute, University of Bristol, Bristol, United Kingdom; and University of Tor Vergata, Rome, Italy

Abstract

Background—There is no accepted consensus on the definition of high-risk patients who may benefit from the use of intraaortic balloon pump (IABP) in coronary artery bypass grafting (CABG). The aim of this study was to develop a risk model to identify high-risk patients and predict the need for IABP insertion during CABG.

Methods—From April 1996 to December 2006, 8,872 consecutive patients underwent isolated CABG; of these 182 patients (2.1%) received intraoperative or postoperative IABP. The scoring risk model was developed in 4,575 patients (derivation dataset) and validated on the remaining patients (validation dataset). Predictive accuracy was evaluated by the area under the receiver operating characteristic curve.

Results—Mortality was 1% in the entire cohort and 18.7% (22 patients) in the group which received IABP. Multivariable analysis showed that age greater than 70 years, moderate and poor left ventricular dysfunction, previous cardiac surgery, emergency operation, left main disease, Canadian Cardiovascular Society 3-4 class, and recent myocardial infarction were independent risk factors for the need of IABP insertion. Three risk groups were identified. The observed probability of receiving IABP and mortality in the validation dataset was 36.4% and 10% in the high-risk group (score >14), 10.9% and 2.8% in the medium-risk group (score 7 to 13), and 1.7% and 0.7% in the low-risk group (score 0 to 6).

Conclusions—This simple clinical risk model based on preoperative clinical data can be used to identify high-risk patients who may benefit from elective insertion of IABP during CABG.

Low cardiac output syndrome occurs in 25 to 9% of patients undergoing cardiac surgery. Despite progress in surgical and anesthetic technique it is still associated with high mortality and morbidity [1-3].

Intraaortic balloon pump (IABP) is the most common mechanical assist device used for the treatment of low cardiac output in patients undergoing coronary artery bypass grafting (CABG) [4]. However, overall mortality in patients receiving intraoperative or postoperative IABP remains high, ranging from 27% to 52% [4-7].

Previous small prospective randomized and observational studies suggest that preoperative IABP insertion in high-risk patients undergoing CABG decreases mortality and morbidity, and shortens postoperative hospital length of stay [8-12]. However, there is no worldwide consensus on the definition of the high-risk patient undergoing CABG. Several risk factors

such as low ejection fraction, advanced age, left main stenosis, redo operation, recent myocardial infarction, poor ejection fraction, and New York Heart Association III-IV class have been identified as predictors of intraoperative or postoperative use of IABP [11-14]. However, we have found no prognostic risk stratification has been developed to predict the need for IABP insertion in patients undergoing CABG. The aim of our study was, therefore, to develop and validate a risk model to identify high-risk patients and predict the need for insertion of IABP during CABG.

Patients and Methods

This was a retrospective, observational, cohort study of prospectively collected data from consecutive patients who underwent CABG at the Bristol Heart Institute between April 1996 and December 2006. The study was approved by the clinical audit committee of the University Hospitals Bristol National Health Service Foundation Trust and individual consent was waived. The data collection form is entered in a database Patient Analysis & Tracking system (Dendrite Clinical System, London, UK) and includes five sections that are filled in consecutively by anesthetists, cardiac surgeons, intensive care and high dependency units, and ward nurses. The base sample contained clinical information about 8,872 patients who underwent CABG. Exclusion criteria were patients in critical preoperative state defined as any one or more of the following: ventricular tachycardia or fibrillation, cardiac massage or aborted sudden death, ventilation before arrival in the anesthetic room, acute renal failure (anuria or oliguria < 10 mL/hour), inotropic support, or IABP [15]. The final study population included 8,747 patients, of whom 2.1% (182 patients) received IABP in the intraoperative or postoperative period. From this sample, 4,575 patients were allocated to the derivation set and 4,172 to the validation set.

Definitions and Risk Factors

The primary outcome was the insertion of intraoperative or postoperative IABP. The indications for IABP support were weaning from cardiopulmonary bypass, hemodynamic support during off-pump surgery, or postoperative low cardiac output syndrome. In-hospital mortality was defined as any death occurring within 30 days of operation. Potential preoperative risk factors for IABP insertion were selected on the basis of the reviewed literature. Poor and moderate ejection fraction (EF) were defined as EF less than 0.30 and EF 0.30 to 0.50, respectively. Preoperative baseline characteristics are listed in Table 1 and definitions have been reported elsewhere [15]. The decision to perform off-pump or on-pump CABG was based on individual surgeon preference. Anesthetic and surgical techniques were standardized for all patients and have been described previously [16, 17].

Statistical Method

The study sample was divided into two datasets; a derivation dataset, which included 4,575 patients undergoing CABG from April 1996 to December 2001 and a validation dataset, which included the remaining 4,172 patients. The scoring model was developed on the derivation dataset. Association between primary endpoint and potential risk factors was assessed by the χ^2 test or Fisher exact test as appropriate. In a second step, all variables with a *p* value of less than 0.2 were then entered into stepwise multivariable logistic regression to identify prediction parameters. We assigned score points to each risk factor using the model parameter estimates and rounded to the nearest integer. As the final step, to validate and assess predictive accuracy, we applied the score system to the validation dataset to evaluate the new score in predicting the intraoperative or postoperative IABP insertion. Accuracy of the models was assessed by receiving operative characteristic curve. Three risk groups were identified: the low-risk group (score 0 to 6), the medium-risk group (7 to 13), and the high-risk group (score >14). Results are reported as percentages and odds ratios (OR) with 95%

confidence interval (CI). All reported p values are two sided, and p values less than 0.05 were considered to indicate statistical significance. Statistical analysis was performed with SPSS 15.0 (SPS Inc, Chicago, IL).

Results

Development and Validation of the Risk Model

The development dataset included 4,575 patients. Overall mortality was 1.1% (50 patients). One hundred and sixteen patients (2.5%) received IABPs, of whom 19% (22 patients) died. Univariate analysis showed that patients receiving IABP were older, were more likely to have higher New York Heart Association class, Canadian Cardiovascular Society class, lower ejection fraction, higher prevalence of previous cardiac operations, emergent procedure, left main stem disease greater than 50%, and recent myocardial infarction (MI) (Table 1). The multivariable logistic regression identified age greater than 70 years (OR 1.75, 95% CI 1.23 to 2.72, $p = 0.003$), previous cardiac operation (OR 3.21, 95% CI 1.69 to 6.09, $p < 0.0001$), emergency operation (OR 3.44, 95% CI 1.52 to 7.8, $p = 0.003$), Canadian Cardiovascular Society 3–4 class (OR 2.44, 95% CI 1.36 to 3.98, $p = 0.001$), ejection fraction between 0.30 and 0.50 (OR 2.14, 95% CI 1.38 to 3.3, $p = 0.001$), ejection fraction less than 0.30 (OR 7.1, 95% CI 4.19 to 11.68, $p < 0.0001$), left main stem disease (OR 1.92, 95% CI 1.21 to 3.05, $p = 0.005$), and recent MI less than 30 days (OR 2.08, 95% CI 1.18 to 3.68, $p = 0.01$) as independent risk factors to predict intraoperative and postoperative IABP insertion in patients undergoing CABG (Table 2). Score points are shown in Table 2. The area under the receiving operative characteristic curve for this model was 0.78 and the Hosmer-Lemeshow goodness-of-fit test was not significant for lack of fit ($p = 0.65$). The resulting score ranges from a minimum of 0 to a maximum of 23. Figure 1 shows a curvilinear relationship between estimated probability of IABP insertion and IABP score. Three risk groups were identified: low-risk (IABP score 0 to 6), medium-risk (IABP score 7 to 13), and high-risk score (IABP score >14). The incidence of IABP and mortality insertion was 1.7% and 0.9% in the low-risk, 10.6% in the medium-risk, and 38.5% in the high-risk group. The C statistic was 0.7, 0.6, and 0.58 in the low-risk, medium-risk, and high-risk groups, respectively. The validation dataset of 4,172 patients was used to validate the IABP score. Overall mortality was 0.9% (39 patients). Sixty-six patients (1.6%) received IABP insertion, of whom 18.2% (12 patients) died. The incidence of IABP insertion and mortality were, respectively, 0.9% and 0.7% in the low-risk group, 7.2% and 2.8% in the medium-risk group, and 36.4% and 9.1% in the high-risk group (Figs 2, 3). Area under the receiving operative characteristic curve was 0.77 for all the validation dataset and 0.67, 0.6, and 0.6 for low, medium, and high-risk groups, respectively. Among high-risk patients (score >14) who receive IABP, mortality was 20% and 25% in the developmental and validation dataset, respectively.

Comment

Low cardiac output syndrome after CABG remains a serious complication with high mortality [1-3]. Using information from our prospectively collected database, we have developed a risk model that identified and stratified patients at risk for low cardiac output after CABG. Multivariable analysis of the developmental dataset showed that age greater than 70 years, previous cardiac operation, emergency operation, Canadian Cardiovascular Society 3-4 class, low ejection fraction (between 0.30 and 0.50 as well as < 0.30), left main stem disease greater than 50, and recent (less than 30 days) MI were independent predictors of IABP insertion. After weighting each factor and developing the risk model, we found that the higher was the numeric score the higher was the estimated probability of IABP insertion (Fig 1). Specifically, patients in the high-risk (score >14) medium-risk (score 7 to 13), and low-risk group (score <6) had 36.4%, 10.6%, and 1.7% probability of IABP insertion,

respectively (Fig 2). The IABP score was also able to identify individuals at increased risk of postoperative death; high, medium, and low-risk groups had 9.1%, 2.8%, and 0.9% observed overall mortality, respectively (Fig 3). This score is simple and codifies well-known risk factors; therefore, it can be easily calculated by physician and nurses from patient history or hospital charts to assess the risk of postoperative low cardiac output syndrome and assist the surgeon in planning the surgery and subsequent postoperative management.

Preoperative identification of high-risk patients undergoing CABG might assist the surgeon in planning the surgery and subsequent postoperative management. There is increasing evidence that in high-risk patients the use of preoperative IABP reduces postoperative mortality, morbidity, and length of hospital stay [8-12]. A recent meta-analysis revealed that preoperative IABP was associated with 3.6% absolute risk reduction in mortality and a 59% reduction in the odds for mortality in high-risk patients undergoing CABG [18]. However, these studies are unpowered and present several limitations. The main limitation regards the controversial and heterogeneous definition of "high-risk patient." A set of liberal criteria has often been used dictated by surgeon's individual experience. Dietl and colleagues [11] suggested that patients with an ejection fraction less than 0.25, and one or more risk factors such as reoperation, unstable angina, use of intravenous nitroglycerine, left main stenosis, acute MI within 7 days, nonelective operation, and New York Heart Association III-IV class, were at high risk for the need of intraoperative and postoperative IABP support [11]. Gutfinger and colleagues [12] defined as high risk those patients older than 70 years having one of the following: left main stenosis greater than 70%, medical refractory unstable angina, ejection fraction less than 0.40, failed percutaneous transluminal coronary angioplasty, or reoperation [12]. Finally, after a series of small prospective trials, Christenson and colleagues [8, 9] defined high-risk patients as those fulfilling at least two of the following criteria: medically refractory unstable angina, ejection fraction less than 0.40, left main stenosis greater than 70%, and redo operation.

The second limitation of those studies is the lack of distinction between therapeutic and prophylactic preoperative IABP insertion. They included patients with uncontrolled myocardial ischemic pain and preoperative cardiogenic shock, which are considered traditional indications for the insertion of IABP. Excluding patients receiving preoperative IABP for hemodynamic instability, shock, recent MI within 3 days, and emergency operation, Holman and colleagues [19] found no survival advantage for use of prophylactic IABP in hemodynamically stable high-risk patients, although they showed a shorter hospital length of stay.

Recently, it has been proposed that the European System for Cardiac Operative Risk Evaluation (EuroSCORE) may direct IABP placement in high-risk patients. Healy and colleagues [20] showed that patients with EuroSCORE greater than 5 who received preoperative IABP had a significantly lower mortality than predicted. However, the evaluation of the risk in the EuroSCORE is based on several risk factors which are not predictors of low cardiac output syndrome. Furthermore, it has been shown that the ability of the EuroSCORE to predict mortality is reduced in high-risk patients [21]. Diez and colleagues [22] found that the EuroSCORE was a valid predictor for perioperative mortality among high-risk nonemergency and emergency patients with preoperative IABP support at a lower score, but failed at a higher score.

It seems, therefore, a worthwhile goal to develop a risk model to identify patients at risk for low cardiac output syndrome who might benefit from elective insertion of IABP during CABG. Our study has achieved these goals by using a large institutional prospectively

collected dataset. However, its main limitation is that it is a single-center retrospective investigation and the results need to be validated in different units.

We have developed a simple risk stratification score system based on preoperative clinical data for identifying high-risk patients who may benefit from elective use of IABP during CABG. These findings now need to be validated with data from other centers.

Acknowledgments

The study was supported by the British Heart Foundation and the National Institute for Health Research Bristol Biomedical Research Unit in Cardiovascular Medicine.

References

1. Rao V. Condition critical: can mechanical support prevent death due to postcardiotomy shock? *J Card Surg.* 2006; 21:238–9. [PubMed: 16684049]
2. Pae WE Jr, Miller CA, Matthews Y, Pierce WS. Ventricular assist devices for postcardiotomy cardiogenic shock: a combined registry experience. *J Thorac Cardiovasc Surg.* 1992; 104:541–52. [PubMed: 1513144]
3. Christenson JT, Buswell L, Velebit V, Maurice J, Simonet F, Schmuziger M. The intraaortic balloon pump for postcardiotomy heart failure. experience with 169 intra-aortic balloon pump. *Thorac Cardiovasc Surg.* 1995; 43:129–33. [PubMed: 7570563]
4. Baskett RJF, Ghali WA, Maitland A, Hirsh GM. The intraaortic balloon pump in cardiac surgery. *Ann Thorac Surg.* 2002; 74:1276–87. [PubMed: 12400798]
5. Creswell LL, Rosenbloom M, Cox JL, et al. Intraaortic balloon counterpulsation: patterns of usage and outcome in cardiac surgery patients. *Ann Thorac Surg.* 1992; 54:11–20. [PubMed: 1610220]
6. Torchiana DF, Hirsh G, Buckley MJ, et al. Intraaortic balloon pumping for cardiac support: trends in practice and outcome, 1968 to 1995. *J Thorac Cardiovasc Surg.* 1997; 113:758–64. [PubMed: 9104986]
7. Arafa OE, Pedersen TH, Svennevig JL, Fosse E, Geiran OR. Intraaortic balloon pump in open heart operations: 10-year follow-up with risk analysis. *Ann Thorac Surg.* 1998; 65:741–7. [PubMed: 9527205]
8. Christenson JT, Simonet F, Badel P, Schmuziger M. Evaluation of preoperative intra-aortic balloon pump support in high risk coronary patients. *Eur J Cardiothorac Surg.* 1997; 11:1097–103. [PubMed: 9237594]
9. Christenson JT, Schmuziger M, Simonet F. Effective surgical management of high-risk coronary patients using preoperative intra-aortic balloon counterpulsation therapy. *Cardiovasc Surg.* 2001; 9:383–90. [PubMed: 11420164]
10. Field ML, Rengarajan A, Khan O, Spyt T, Richens D. Preoperative intra aortic balloon pumps in patients undergoing coronary artery bypass grafting. *Cochrane Database Syst Rev.* 2007; 24 CD004472.
11. Dietl C, Berkheimer M, Woods E, Gilbert C, Pharr W, Benoit C. Efficacy and cost-effectiveness of preoperative IABP in patient with ejection fraction of 0.25 or less. *Ann Thorac Surg.* 1996; 62:401–9. [PubMed: 8694598]
12. Gutfinger DE, Ott RA, Miller M, et al. Aggressive preoperative use of intraaortic balloon pump in elderly patients undergoing coronary artery. *Ann Thorac Surg.* 1999; 67:610–3. [PubMed: 10215196]
13. Creswell LL, Moulton MJ, Cox JL, Rosebloom M. Revascularization after acute myocardial infarction. *Ann Thorac Surg.* 1995; 60:19–26. [PubMed: 7598589]
14. Rao V, Ivanov J, Weisel RD, Ikonomidis JS, Christakis GT, David TE. Predictors of low cardiac output syndrome after coronary artery bypass. *J Thorac Cardiovasc Surg.* 1996; 112:38–51. [PubMed: 8691884]

15. Roques F, Nashef SAM, Micheal P, et al. Risk factors and outcome in European cardiac surgery: analysis of the EuroSCORE multinational database of 19030 patients. *Eur J Cardiothorac Surg.* 1999; 15:816–23. [PubMed: 10431864]
16. Ascione R, Caputo M, Calori G, Lloyd CT, Underwood MJ, Angelini GD. Predictors of atrial fibrillation after conventional and beating heart coronary surgery: a prospective randomized study. *Circulation.* 2000; 102:1530–5. [PubMed: 11004144]
17. Watters MP, Ascione R, Ryder IG, Ciulli F, Pitsis AA, Angelini GD. Hemodynamic changes during beating heart coronary surgery with the “Bristol Technique”. *Eur J Cardiothorac Surg.* 2001; 19:34–40. [PubMed: 11163558]
18. Dyub AM, Whitlock RP, Abouzahr LL, Cinà CS. Preoperative intra-aortic balloon pump in patients undergoing coronary bypass surgery: a systematic review and meta-analysis. *J Card Surg.* 2008; 23:79–86. [PubMed: 18290898]
19. Holmann WL, Li Q, Kiefe C, et al. Prophylactic value of preincision intra-aortic balloon pump: analysis of a statewide experience. *J Thorac Cardiovasc Surg.* 2000; 120:1112–9. [PubMed: 11088035]
20. Healy DG, Veersasingam D, Wood AE. EuroSCORE: useful in directing preoperative intra-aortic balloon pump placement in cardiac surgery? *Heart Surg Forum.* 2006; 9:E893–6. [PubMed: 17599889]
21. Shanmugan G, West M, Berg G. Additive and logistic EuroSCORE performance in high risk patients. *Interact Cardiovasc Thorac Surg.* 2005; 4:299–303. [PubMed: 17670417]
22. Diez C, Silber RE, Wächner M, Stiller M, Hofmann H-S. EuroSCORE directed intraaortic balloon pump placement in high-risk patients undergoing cardiac surgery-retrospective analysis of 267 patients. *Interact Cardiovasc Thorac Surg.* 2008; 7:389–95. [PubMed: 18256116]

Fig 1.
Relationship between risk score and probability of intraoperative or postoperative intraaortic balloon pump (IABP) insertion.

Fig 2. Probability of intraoperative or postoperative intraaortic balloon pump (IABP) insertion according to group score. (Black column = developmental dataset; grey column = validation dataset.)

Fig 3. Probability of death according to group score. (Black column = developmental dataset; grey column = validation dataset.)

Table 1

Results of Univariate Analysis

Variable	N (%)	OR	p Value
Age > 70 years	44 (37.9)	2.169	<0.0001
Female	29 (25)	1.426	0.129
Hypertension	67 (57.8)	1.002	1
Diabetes	20 (17.2)	1.343	0.295
CCS 3–4 class	99 (85.3)	3.514	<0.0001
NYHA 3–4 class	61 (52.6)	2.104	<0.0001
Chronic pulmonary disease	12 (10.3)	1.087	0.913
Extracardiac arteriopathy	12 (10.3)	1.136	0.801
Previous cardiac surgery	13 (11.2)	4.074	<0.0001
Serum creatinine > 200 μ mol/L	4 (3.4)	2.341	0.196
Moderate EF	0.40 (34.5)	1.811	0.004
Poor EF	0.27 (23.3)	6.46	<0.0001
Interval between MI and surgery (<30 days)	17 (14.7)	3.582	<0.0001
Interval between MI and surgery (31 to 90 days)	41 (35.3)	0.846	0.451
Left main stem disease (>50%)	27 (23.3)	2.161	<0.0001
Emergency surgery	9 (7.8)	7.129	<0.0001

CCS = Canadian cardiovascular society; EF = ejection fraction; MI = myocardial infarction; NYHA = New York heart association; OR = odds ratio.

Table 2

Results of Multivariable Analysis

Variable	Risk Score	OR	95% CI	<i>p</i> Value
Age >70 years	2	1.753	1.227–2.716	0.003
CCS 3–4 class	2	2.44	1.365–3.984	0.001
Previous cardiac surgery	3	3.213	1.694–6.093	<0.0001
Moderate EF	2	2.142	1.388–3.306	0.001
Poor EF	7	7.001	4.194–11.686	<0.0001
Interval between MI and surgery (< 30 days)	2	2.083	1.18–3.678	0.01
Left main stem disease (>50%)	2	1.923	1.214–3.048	0.005
Emergency surgery	3	3.442	1.519–7.8	0.003

Hosmer-Lemeshow goodness of fit was 3.09 ($p = 0.687$), C index for the model was 0.79.

CCS = Canadian Cardiovascular Society; CI = confidence interval; EF = ejection fraction; MI = myocardial infarction; OR = odds ratio.