Multidiscip Cardio Annal. 2016 October; 7(1):e9058. doi: 10.17795/mcardia.9058.

Published online 2016 September 26.

Research Article

Development of an Iranian CPB Based Risk Stratification Score Model, an Iranian Risk Stratification Model

Mahdi Daliri,[1,*] Ahmad Rajaii-Khorasani,[2] Mehdi Jabbari Noghabi,[3] and Mona Yadollahi[4]

[1]Department of Cardiac Surgery, Rajaie Cardiovascular Medical and Research Center, Iran University of Medical Sciences, Tehran, IR Iran
[2]Department of Cardiothoracic Surgery, Razavi Hospital, Mashhad, IR Iran
[3]Surgical Oncology Research Center, Emam Reza Hospital, Faculty of Medicine, Mashhad University of Medical Sciences, Mashhad, IR Iran
[4]Department of Cardiology, Rajaie Cardiovascular Medical and Research Center, Iran University of Medical Sciences, Tehran, IR Iran

[*]*Corresponding author*: Mahdi Daliri, MD, Rajaei Cardiovascular Medical and Research Center, Valiasr Ave, Niayesh Intersection, Tehran, IR Iran. Tel: +98-9151040818, E-mail: m_daliri@yahoo.com

Received 2016 August 06; **Revised** 2016 August 30; **Accepted** 2016 September 20.

Abstract

Background: This study evaluates cardiopulmonary bypass (CPB) as a predictor of 30-day postoperative mortality and modifies Parsonnet and Euro SCORE models accordingly to develop a new model.

Methods: Information of 1920 consecutive patients who underwent elective and emergent surgery in our center was collected. Parsonnet and Euro SCORE model parameters in addition to 81 variables including perioperative information gathered. Following statistical analysis by R software a new model considering CPB under the name of Iranian model was designed. Parsonnet and Euro SCORE models were recalibrated and CPB variable was entered. Data validation was performed in 40 consecutive patients.

Results: P value of our five predictor models including Iranian, Parsonnet (P) and modified Parsonnet (MP), Euro SCORE (ES) and modified Euro SCORE (MES) models were < 2e-16. Iranian model has a lower overestimation of mortality (0.4375) and its area under curve (AUC) was higher (0.9537). AUC of P, MP, ES and MES models were 0.9551, 0.9841, 0.8659 and 0.9465 respectively. Overestimation of early post operative mortality of P, MP, ES and MES models were 0.6483, 0.5271, 0.6267 and 0.5056 respectively.

Conclusions: This study confirmed that CPB as a variable is a predictor of mortality and is applicable in risk stratification models. CPB increases AUC and decreases Overestimation of mortality. Iranian model as the first CPB dependent mortality prediction model has more accurate mortality estimation in respect to other models.

Keywords: CPB, Risk Model

1. Background

Despite improvements in technology and surgeons' experience, open-heart surgery still portends a risk of mortality and morbidity (1), therefore investigators have tried to decrease complications by appropriate selection of patients.

Operative mortality represents an indicator of cardiac surgery quality (2). Interest to estimate operative mortality, has led to designation of several predictive models (3). Most of the models are multifactorial including preoperative information, operation data and 30-days post outcomes. One of the first scoring algorithms formulated by Parsonnet in 1989 (4) and thereafter more risk score calculators developed.

Difference between institutions and geographic areas necessitates local risk models (1). The most populated models include Euro SCORE, Parsonnet, 2000 Bernstein-Parsonnet (BP) estimation score, the Society of Thoracic Surgeons (STS) algorithm and United Kingdom score models (5-8).

On the other hands, off-pump coronary artery bypass grafting (OPCAB) is gaining world wide acceptance and the number of OPCAB procedures is increasing (9). Several studies have evaluated the validity of populated mortality score models in OPCAB patients (9, 10). Cardiopulmonary bypass (CPB) technique is a paramount factor that can affect operative mortality but no model has inserted this risk factor in multivariate analysis. Conversion of OPCAB to On-pump coronary artery bypass grafting (ONCAB) deserves attention indeed.

Respect to wide spread usage of OPCAB technique, the aim of this study is to designate a mortality score model including CPB technique and conversion to ONCAB as a new factor and its comparison with Parsonnet and Euro SCORE model because of their popularity.

2. Methods

2.1. Patients' Populations

The study has been performed in the cardiothoracic surgery department of Razavi hospital. 1920 consecutive patients who underwent emergent and elective cardiac surgery from April 2009 to March 2011 entered. Patients' data were collected while in hospital according to a comprehensive database including 445 variables and stored in a Razavi adult cardiac surgery database.

2.2. Data Collection

The most relevant 81 patients related variables are depicted in Table 1 combined with 39 items derived from Parsonnet, and Euro SCORE variables were imported into the statistical software (Table 1). Before calculation missing data were excluded from database.

2.3. CPB Dependent Models

Our model named as Iranian model was designed by entering variable relevant to CBP into standard logistic Euro SCORE and Parsonnet model. Mean post operative and 30 days mortality was calculated by each model and the actual mortality was compared with each other.

2.4. Statistical Analysis

Since the utilized models are very complicated and large in size and in order to get better results, the R software and relative packages were applied. To check the ability of entering variables, we used the cross tabulation tables, Chisquare and Fisher's exact test. If any significant correlation between mortality and the explanatory variables exist at the level of two percent (0.2), variable was inserted. The best model to fit the data is Binomial Logistic Regression. After finding the best model, we checked the adequacy of the final models.

Discrimination can be assessed by the area under the receiver operative characteristic curve (ROC). The ROC area can be interpreted as the probability that a patient who died had a higher risk score than a patient who survived. Thus the area under the curve is the percentage of randomly drawn pairs for which this is true. This is a fairly subjective measure and values greater than 0.8 usually indicate potentially useful discrimination. A value of 0.5 indicates random predictions.

The AIC statistic (2(log-likelihood) + 2(number of parameters in the model)) increases with an increasing number of coefficients but decreases when a better adaptability to data is achieved. It represents the measure of how much a specific model is suitable to describe the study phenomenon and is a function of the model's residual variance (prediction error): the less the variance the more the accuracy. According to Akaike, the model exhibiting the smallest AIC value is the model providing the most information on the study sample (11).

3. Results

3.1. Patients' Variables

The mean age of the 1920 patients was 59 $\pm$ 12.5 years, 69.1% were men.

Coronary artery bypass grafting (CABG) consisted 90.7% of surgeries along with 2.8 $\pm$ 1.6 grafts in each patient, compared to 9.9 % valve surgery and 3.8 % aortic surgery respectively. 78.7 % of operations were using off – pump technique and in 15 (0.8%) the operation was converted to on- pump technique.

Coronary patients suffered from 1.96% overall and 0.44% off pump mortality (Table 1).

3.2. Euro SCORE and Parsonnet Variables

After excluding missing data, 936 patients entered. Additive and logistic scores were evaluated (Table 2). EuroSCORE estimated mortality 8.4 $\pm$ 10.8 by logistic model. Parsonnet additive model estimated mortality 6.2 $\pm$ 9.98. These two models overestimate mortality in comparison to 2.3 % in our patients.

3.3. Euro SCORE Model (with or without CPB)

CPB as a variable was inserted to this model and analyzed again. The P value of these two models were < 2e-16. Results manifested that CPB decreased overestimation of the model and better estimated mortality rate. Mortality of Euro SCORE including CPB or not were 0.6267039 and 0.5056874 (Table 3).

3.4. Parsonnet Model (with or without CPB)

Parsonnet model was recalibrated by entering CPB and analyzed again. The p value of these two models were < 2e-16. Overestimation of mortality of Standard Parsonnet and CPB dependent Parsonnet models were 0.6483348 and 0.5271963 (Table 4).

3.5. CPB Dependent Risk Prediction Model (Iranian Model)

Firstly all variables of 1920 patients were analyzed by SPSS 19 software and the items with P < 0.2 were selected and entered while others were excluded. New items include using prophylactic or therapeutic drugs like ASA, Digoxin and oral hypoglycemic drugs, laboratory data like INR and Potassium, number of coronary grafts, pericardial effusion and utilization of cardiopulmonary bypass.

Then significant variables were entered into R software to heighten sensitivity and multivariable analysis was performed. P value of model was < 2e-16 and over estimation was considered 0.4375621 (Table 5).

Table 2. Frequencies of Euro SCORE and Parsonnet Models Variables

Variables	Euro SCORE n =936 (100%)	Parsonnet n = 936 (100%)
Age	936 (mean = 59 ± 12.6)	936 (mean = 59 ± 12.6)
Sex (Female)	298(31.8)	298 (31.8)
Family history	*[a]	138 (14.7)
Obesity	*	401 (42.8)
Smoking	*	151 (16)
Chronic pulmonary disease	9 (1)	*
Extracardiac arteriopathy	22 (2.4)	*
Neurologic dysfunction	27 (2.9)	*
Previous cardiac surgery (Reoperation)	38 (4.1)	38 (4.1)
Elevated cholesterol	*	374 (40)
Diabetes	*	311 (33.2)
Cr > 200	27 (2.9)	*
Active endocarditis	1 (0.1)	*
Critical preoperative or catastrophic state	32 (3.4)	32 (3.4)
Unstable angina	831 (88.8)	*
LVEF ≥ 50	*	611 (65.3)
LVEF 30- 50	297 (31.7)	297 (31.7)
LVEF < 30	28 (3)	28 (3)
Recent myocardial infarct	159 (17)	*
Hypertension	*	478 (51.1)
Pulmonary HTN	152 (16.2)	*
Left ventricular aneurysm	*	18 (1.9)
Emergency	370 (39.5)	*
Other than isolated CABG	87 (9.3)	*
Surgery on thoracic surgery	30 (3.2)	*
Post infarct septal rupture	2 (0.2)	*
Mitral valve disease	*	94 (10)
Aortic valve disease	*	73 (7.8)
Bypass only	*	766 (81.8)
Bypass + other procedure	*	112 (12)
Preoperative IABP	*	20 (2.1)
Logistic	936 (mean = 8.4 ± 10.86)	936 (mean = 6.2 ± 9.98)

[a] Absence of the variable.

Table 3. Description of the Risk Factors of Standard Euro SCORE and Modified CPB Dependent Logistic Euro SCORE Models

	R Software Estimation					
	Standard Euro SCORE			Euro SCORE with CPB		
	β-Coefficients	P Value	Odds Ratio	β-Coefficients	P Value	Odds Ratio
Models	2.3565619	< 2e-16	10.5546013	2.6210549	< 2e-16	13.7502217
Age	-0.0004246	0.2816	0.9995755	-0.0004270	0.330268	0.9995731
Sex (Female)	0.0007991	0.9349	1.0007994	0.0060938	0.557565	1.0061124
Chronic pulmonary disease	-0.0887302	0.0601	0.9150924	-0.1701578	0.006595	0.8435317
Extracardiac arteriopathy	0.0288982	0.4014	1.0293198	-0.0129948	0.735969	0.9870893
Neurologic dysfunction	-0.0089976	0.7418	0.9910427	-0.0056736	0.845662	0.9943425
Previous cardiac surgery	-0.0228136	0.4272	0.9774447	-0.0126495	0.709815	0.9874302
Cr > 200	-0.0476118	0.0707	0.9535038	-0.0303943	0.259217	0.9700630
Active endocarditis	0.1889532	0.1269	1.2079844	-	-	-
Critical preoperative state	-0.0270895	0.5244	0.9732741	-0.0135486	0.755364	0.9865428
Unstable angina	-0.0331772	0.0567	0.9673672	-0.0431091	0.036204	0.9578069
LVEF 30-50	-0.0138649	0.1689	0.9862308	-0.0136257	0.201685	0.9864667
LVEF < 30	-0.1386966	9.7e-07	0.8704921	-0.1299868	1.07e-05	0.8781070
Recent MI	-0.0138612	0.2764	0.9862344	-0.0179571	0.174965	0.9822032
Pulmonary HTN	-0.0102687	0.4274	0.9897838	-0.0065314	0.642917	0.9934899
Emergency	0.0019060	0.8487	1.0019078	0.0059007	0.575283	1.0059181
Other than isolated CABG	-0.0605301	0.0084	0.9412654	-0.0509750	0.068248	0.9503024
Surgery on thorax	-0.1162545	0.0102	0.8902487	-0.1347036	0.007551	0.8739749
Post infarct septal rupture	-0.0039948	0.9732	0.9960132	-0.0109594	0.927477	0.9891004
CPB Elective On-pump	-	-	-	0.0544777	0.000175	1.0559889
Emergent On-pump	-	-	-	-0.0150403	0.730744	0.9850722

3.6. Comparison Between Models

Analysis revealed that P value of all models were < 2e-16, however Iranian model possessed the highest accuracy for mortality evaluation and the lowest overestimation of mortality (0.4375621%), followed by Euro SCORE including CPB (0.5056874%), Parsonnet with CPB (0.5271963%), Euro SCORE (0.6267039%) and Parsonnet (0.6483348%) (Table 6).

Results showed that new version of Parsonnet model with new calibration and β-coefficients of variables has the least number of mistakes in estimation of mortality and the lowest Akaike information criterion (AIC) score (-1246.7561), followed by Parsonnet with CPB (-1122.1585), Euro SCORE (-978.0662), Iranian model (-917.1253) and Euro SCORE with CPB (-889.2239).

Finally ROC curve of models showed better area under curve (AUC) for CPB dependent Parsonnet models (0.9841) in comparison with standard Parsonnet (0.9551), Iranian model (0.9537), CPB dependent Euro SCORE (0.9465) and Euro SCORE (0.8659) (Table 6).

Iranian model had the lowest overestimation in predicting mortality and recalibrated Parsonnet model had the highest AUC overall. The point is by entering CPB variable, AUC increased and overestimation of mortality decreased. For example in Euro SCORE AUC and overesti-

Table 4. Description of the Risk Factors of Standard Parsonnet and Modified CPB Dependent Parsonnet Models

	R Software Estimation					
	Standard Parsonnet			Parsonnet with CPB		
	β-Coefficients	P Value	Odds Ratio	β-Coefficients	P Value	Odds Ratio
Models	2.5262934	< 2e-16	12.5070608	2.6210549	< 2e-16	12.3642165
Age	-0.0002181	0.5158	0.9997819	-0.0003252	0.3892	0.9996749
Aortic valve disease	-0.0295881	0.1560	0.9708454	-0.0419241	0.1139	0.9589425
Bypass only	0.0129231	0.5606	1.0130069	0.0103973	0.7474	1.0104516
Bypass + other procedure	-0.0143125	0.4963	0.9857895	-0.0012928	0.9649	0.9987080
Elevated choles-terol	-0.0029976	0.7226	0.9970068	-0.0019665	0.8249	0.9980354
Diabetes	0.0152010	0.0802	1.0153172	0.015511	0.0919	1.0156324
Catastrophic state	-0.3707541	< 2e-16	0.6902136	-0.3530895	< 2e-16	0.7025143
Family History	-0.0062570	0.59365	0.9937625	-0.0071385	0.5640	0.9928869
LVEF $\geq$ 50	-0.0090615	0.2822	0.9909794	-0.0085382	0.3438	0.9914981
LVEF < 30	0.0371762	0.1185	1.0378758	0.0393746	0.1285	1.0401601
Sex (Female)	-0.0036464	0.6762	0.9963603	-0.0079582	0.4017	0.9920734
Hypertension	-0.0053491	0.5206	0.9946651	-0.0048081	0.5854	0.9952034
Left ven-tricular aneurysm	0.0329689	0.2824	1.0335184	0.0338604	0.2843	1.0344402
Mitral valve disease	0.0399200	0.0188	1.0407275	0.0494661	0.0143	1.0507100
Obesity	0.0109287	0.1689	1.0109886	0.0109364	0.1964	1.0109964
Preoperative IABP	-0.1833704	2.72e-10	0.8324597	-0.1983621	2.48e-10	0.8200729
Reoperation	0.0112891	0.5953	1.0113531	0.0162706	0.5272	1.0164037
Smoking	0.0045735	0.6415	1.0045840	0.0039034	0.7039	1.0039110
CPB Elective On-pump	-	-	-	0.0322004	0.0240	1.0327244
Emergent On-pump	-	-	-	-0.0335339	0.3614	0.9670222

mation of mortality changed from 0.8659 to 0.9465 and 0.6267 to 0.5056 respectively.

4. Discussion

Our main purpose was to evaluate cardiopulmonary bypass effect on 30-day postoperative mortality besides designing a new model for better estimation of mortality in OPCAB and ONCAB patients. Until now, no model with CPB variable is available.

OPCAB technique is gaining more popularity worldwide and surgeons' experiences are increasing 11. However a question still exists. Which one is superior? On pump or off pump? (12). Some investigators tried some models for better estimation of mortality in these two groups. Hirose et al in 2010 assessed mortality in CABG group by Euro SCORE model (13). They concluded that Euro SCORE was not an appropriate risk stratification model for off pump patients and should be modified.

Parolari et al (14) in 2009 estimated postoperative mortality in 1140 OPCAB and 3440 ONCAB patients by additive and logistic Euro SCORE models and finally reported no significant difference between these two groups. ROCs of additive Euro SCORE were 0.808 and 0.779 in ONCAB and OPCAB whereas ROCs of Logistic Euro SCORE included 0.813 and 0.773 in ONCAB and OPCAB, respectively. Mortality overestimation was noticed in both models. Farrokhyar et al in 2007 estimated a good prediction of mortality in on and off pump by using society of thoracic surgeons (STS) and Euro SCORE models although CPB had not been evaluated (15). ROC curve of STS for off-pump and on-pump was 0.81 and 0.82 and by Euro SCORE was 0.79 and 0.81 respectively. Similarly Toumpoulis et al in 2004 evaluated Euro SCORE model in CABG patients and reported logistic and standard Euro SCORE model were strong predictor models in CABG patients (16).

Two clinical trials reported difference between ONCAB and OPCAB mortality and both study showed lower mortality and morbidity in OPCAB group. Calafiore et al in 2001 reported CPB as an independent risk factor for higher morbidity and mortality (17). Al-Ruzzeh et al in 2003 used mortality prediction model reported by the Society of Cardiothoracic Surgeons of Great Britain and Ireland (SCTS) and reported OPCAB group had a lower mortality in UK national database (10). Our findings accommodate with the last studies mentioned. OPCAB group mortality was lower than ONCAB patients (0.44% (3 of 674) Vs. 8.69 (10 of 115)). Possible explanation of higher ONCAB mortality rate is that patients are operated using OPCAB technique except those who could not tolerate and converted to ONCAB or another operation than CABG should be performed such as valve surgery plus CABG.

Because of demographic differences among countries specified prediction models should be applied. Euro SCORE model is a good mortality predictor in Europe and North America (14) however, it may overestimate postoperative risk and require recalibration in different countries. Youn et al. reported overestimation of prediction in Korea (observed mortality 1.3% Vs. Logistic and standard Euro SCORE prediction 4.5% and 5% respectively) (9). Yap et al in 2006 reported Euro SCORE as an inappropriate model in Australia and should be recalibrated (Observed 3.2% Vs. additive and logistic 5.31% and 8.76% respectively) (18), the same as in Denmark and Italy (19, 20). Parsonnet score is a simple prediction model but like Euro SCORE model it would not be suitable for many populations and should be

Table 5. Description of the Risk Factors of CPB Dependent Mortality Prediction Model

	R Software Estimation			
	β-Coefficients	Std. Error	P Value	Odds Ratio
Model	2.000e + 00	7.510e-02	< 2e-16	7.3862786
Age	3.265e-05	4.549e-04	0.942820	1.0000326
EF				
< 30	-3.277e-02	1.951e-02	0.093568	0.9668893
30 - 49	-3.367e-02	1.870e-02	0.072268	0.9677575
Number of graft				
1	-8.805e-03	4.086e-02	0.829472	0.9912338
2	-3.089e-03	2.802e-02	0.912265	0.9969159
3	1.115e-02	2.370e-02	0.637990	1.0112173
4	8.321e-03	2.383e-02	0.727063	1.0083562
5	1.083e-02	2.561e-02	0.672642	1.0108850
6	5.756e-02	3.482e-02	0.098853	1.0592462
Female	1.281e-02	1.082e-02	0.237140	1.0128903
Previous hear surgery	-3.303e-02	4.276e-02	0.440125	0.9675089
No using oral hypoglycemic agent	1.349e-02	1.153e-02	0.242673	1.0135814
No Using ASA	8.020e-03	1.345e-02	0.551323	1.0080522
No Using Digoxin	-3.167e-02	2.913e-02	0.277507	0.9688279
SBP	2.926e-03	1.026e-02	0.775509	1.0029302
12 - 14				
14 - 16	2.579e-02	3.540e-02	0.466541	1.0261285
> 16	-1.105e-02	5.289e-02	0.834563	0.9890091
Cr				
1 - 1.5	-1.734e-02	1.384e-02	0.210745	0.9828113
1.5 - 2	-1.585e-02	1.926e-02	0.410810	0.9842768
> 2	7.893e-03	2.787e-02	0.777081	1.0079244
K				
3.5 - 5	1.022e-02	3.390e-02	0.763196	1.0102710
> 5	2.546e-02	3.763e-02	0.498880	1.0257905
INR				
1 - 1.5	-9.936e-03	9.628e-03	0.302521	0.9901136
> 1.5	1.276e-02	2.748e-02	0.642481	1.0128461
RCA severe stenosis	3.445e-02	1.498e-02	0.021794	1.0350543
Pericardial effusion	2.108e-01	5.409e-02	0.000108	1.2347198
Aorta aneurysm	-4.370e-01	1.444e-01	0.002585	0.6460036
Location of aorta aneurysm				
Asc.	2.239e-01	1.457e-01	0.124927	1.0129734
Asc. and Trans.	1.289e-02	1.782e-01	0.942370	1.2509967
Aorta dissection	4.365e-01	1.217e-01	0.000362	1.5472335
CABG	7.845e-02	4.086e-02	0.055372	1.0816058
Valve surgery	-4.492e-02	5.396e-02	0.405550	0.9560783
Bental	4.095e-01	8.733e-02	3.41e-06	1.5061298
CPB				
Elective On-pump	-5.274e-02	1.623e-02	0.001224	1.0541516
Emergent On-pump	-5.943e-04	4.477e-02	0.989414	1.0005945
Name of valve				
Aortic	5.492e-02	5.285e-02	0.299160	1.0564510
Aortic and mitral	6.064e-02	9.850e-02	0.538363	1.0625164
Mitral	5.870e-02	5.499e-02	0.286247	1.0604534
Mitral and Tric.	2.173e-02	9.835e-02	0.825181	1.0219726
Other single V.	1.761e-02	1.272e-01	0.889978	1.0177624
Triple V.	-1.430e-02	1.299e-01	0.912369	0.9858049

Table 6. Comparison Between Models

Model	Statistical Parameters					
	P Value	Std. Error	β-Coefficients	AIC	Overestimation of Mortality, %	AUC
Euro SCORE	< 2e-16	0.1916119	2.3565619	-978.0662	0.6267039	0.8659
Parsonnet	< 2e-16	0.0635907	2.5262934	-1246.7561	0.6483348	0.9551
Euro SCORE with CPB	< 2e-16	0.1578970	2.6210549	-889.2239	0.5056874	0.9465
Parsonnet with CPB	< 2e-16	0.0731615	2.5148065	-1122.1585	0.5271963	0.9841
Iranian model (CPB dependent)	< 2e-16	0.0751000	2.0000000	-917.1253	0.4375621	0.9537

Abbreviations: AIC, akaike information criterion; AUC, area under curve; CPB, cardiopulmonary bypass; Std, standard; < 2e-16, $< 2 \times 10^{-16}$.

recalibrated. Varennes et al in 2007 used Parsonnet score for prediction of mortality in Canadian patients and results showed overall mortality was 6.4 vs. model estimation which was 18.8 $\pm$ 13.7 (21).

Accordingly, our results depicted overall mortality was 2.3% and estimation for logistic Euro SCORE was 8.4 $\pm$ 10.86 and for Parsonnet score was 6.2 $\pm$ 9.98. Therefore recalibration was performed (Tables 3 and 4). Overestimation changed to 0.6267039 and 0.6483348 after modification of Euro Score and Parsonnet models respectively.

After considering CPB as a variable, results indicated significant decrease in overestimation (0.6267039 to 0.5056874 for Euro Score and 0.6483348 to 0.5271963 for Parsonnet). So CPB significantly accentuated the accuracy of mortality prediction.

Comparing other models, Iranian model includes the lowest overestimation (0.4375621). Regarding new variables, aortic surgery encompassing Bental operation (P value 3.41×10^{-6}), aortic dissection (P value 0.000362), aortic aneurysm (P value 0.002585) signifies higher early mortality. Pericardial effusion (P value 0.000108) along with CPB especially in emergent situations (P value 0.001224) significantly augments postoperative mortality. Conversely, consuming drugs preoperatively lessens early mortality irrespective of time duration.

Although our study was single centered and limited in respect to the number of patients, we developed a new risk prediction model of postoperative mortality named as Iranian model. By inserting CPB and other variables into existing models we claim that our model accommodates better with mortality rate. It has been justified with our demographic characteristics and has reduced overestimation of mortality comparing to Euro SCORE and Parsonnet.

In fact, this study suggests inserting CPB as a determinant variable in predicting mortality. In case of application of popular predictor models recalibration considering demographic characteristics seems necessary.

References

1. Nilsson J, Algotsson L, Hoglund P, Luhrs C, Brandt J. Comparison of 19 pre-operative risk stratification models in open-heart surgery. *Eur Heart J.* 2006;**27**(7):867–74. doi: 10.1093/eurheartj/ehi720. [PubMed: 16421172].
2. Bridgewater B, Neve H, Moat N, Hooper T, Jones M. Predicting operative risk for coronary artery surgery in the United Kingdom: a comparison of various risk prediction algorithms. *Heart.* 1998;**79**(4):350–5. [PubMed: 9616341].
3. Berman M, Stamler A, Sahar G, Georghiou GP, Sharoni E, Brauner R, et al. Validation of the 2000 Bernstein-Parsonnet score versus the EuroSCORE as a prognostic tool in cardiac surgery. *Ann Thorac Surg.* 2006;**81**(2):537–40. doi: 10.1016/j.athoracsur.2005.08.017. [PubMed: 16427846].
4. Parsonnet V, Dean D, Bernstein AD. A method of uniform stratification of risk for evaluating the results of surgery in acquired adult heart disease. *Circulation.* 1989;**79**(6 Pt 2):I3–12. [PubMed: 2720942].
5. Roques F, Nashef SA, Michel P, Gauducheau E, de Vincentiis C, Baudet E, 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**(6):816–22. [PubMed: 10431864] discussion 822-3.
6. Bernstein AD, Parsonnet V. Bedside estimation of risk as an aid for decision-making in cardiac surgery. *Ann Thorac Surg.* 2000;**69**(3):823–8. [PubMed: 10750767].
7. Edwards FH, Clark RE, Schwartz M. Coronary artery bypass grafting: the Society of Thoracic Surgeons National Database experience. *Ann Thorac Surg.* 1994;**57**(1):12–9. [PubMed: 8279877].
8. Society of Cardiothoracic Surgeons of Great Britain and Ireland National Database . Preliminary report 1996. In conjunction with the MRC Biostatistics Unit Cambridge and Dendrite Clinical systems (UK) Ltd. ; 1996.
9. Youn YN, Kwak YL, Yoo KJ. Can the EuroSCORE predict the early and mid-term mortality after off-pump coronary artery bypass grafting?. *Ann Thorac Surg.* 2007;**83**(6):2111–7. doi: 10.1016/j.athoracsur.2007.02.060. [PubMed: 17532408].
10. Al-Ruzzeh S, Ambler G, Asimakopoulos G, Omar RZ, Hasan R, Fabri B, et al. Off-Pump Coronary Artery Bypass (OPCAB) surgery reduces risk-stratified morbidity and mortality: a United Kingdom Multi-Center Comparative Analysis of Early Clinical Outcome. *Circulation.* 2003;**108 Suppl 1**:II1–8. doi: 10.1161/01.cir.0000087440.59920.a1. [PubMed: 12970199].
11. Akaike H. Statistical predictor identification. *Ann Inst Statistic Math.* 1970;**22**(1):203–17.
12. Sabik JF, Gillinov AM, Blackstone EH, Vacha C, Houghtaling PL, Navia J, et al. Does off-pump coronary surgery reduce morbidity and mortality?. *J Thorac Cardiovasc Surg.* 2002;**124**(4):698–707. [PubMed: 12324727].
13. Hirose H, Noguchi C, Inaba H, Tambara K, Yamamoto T, Yamasaki M, et al. The role of EuroSCORE in patients undergoing off-pump coronary artery bypass. *Interact Cardiovasc Thorac Surg.* 2010;**10**(5):771–6. doi: 10.1510/icvts.2009.226803. [PubMed: 20103507].
14. Parolari A, Pesce LL, Trezzi M, Loardi C, Kassem S, Brambillasca C, et al. Performance of EuroSCORE in CABG and off-pump coronary artery bypass grafting: single institution experience and meta-analysis. *Eur Heart J.* 2009;**30**(3):297–304. doi: 10.1093/eurheartj/ehn581. [PubMed: 19141560].
15. Farrokhyar F, Wang X, Kent R, Lamy A. Early mortality from off-pump and on-pump coronary bypass surgery in Canada: a comparison of the STS and the EuroSCORE risk prediction algorithms. *Can J Cardiol.* 2007;**23**(11):879–83. [PubMed: 17876379].
16. Toumpoulis IK, Anagnostopoulos CE, DeRose JJ, Swistel DG. European system for cardiac operative risk evaluation predicts long-term survival in patients with coronary artery bypass grafting. *Eur J Cardiothorac Surg.* 2004;**25**(1):51–8. [PubMed: 14690732].
17. Calafiore AM, Di Mauro M, Contini M, Di Giammarco G, Pano M, Vitolla G, et al. Myocardial revascularization with and without cardiopulmonary bypass in multivessel disease: impact of the strategy on early outcome. *Ann Thorac Surg.* 2001;**72**(2):456–62. [PubMed: 11515882] discussion 462-3.
18. Yap CH, Reid C, Yii M, Rowland MA, Mohajeri M, Skillington PD, et al. Validation of the EuroSCORE model in Australia. *Eur J Cardiothorac Surg.* 2006;**29**(4):441–6. doi: 10.1016/j.ejcts.2005.12.046. [PubMed: 16473519] discussion 446.
19. Matyal R, Hess PE, Asopa A, Zhao X, Panzica PJ, Mahmood F. Monitoring the variation in myocardial function with the Doppler-derived myocardial performance index during aortic cross-clamping. *J Cardiothorac Vasc Anesth.* 2012;**26**(2):204–8. doi: 10.1053/j.jvca.2011.09.017. [PubMed: 22100856].
20. D'Errigo P, Seccareccia F, Rosato S, Manno V, Badoni G, Fusco D, et al. Comparison between an empirically derived model and the EuroSCORE system in the evaluation of hospital performance: the example of the Italian CABG Outcome Project. *Eur J Cardiothorac Surg.* 2008;**33**(3):325–33. doi: 10.1016/j.ejcts.2007.12.001. [PubMed: 18201891].
21. de Varennes B, Lachapelle K, Cecere R, Ergina P, Shum-Tim D, Tchervenkov C, et al. Application of the Parsonnet scoring system for a Canadian cardiac surgery program. *Can J Cardiol.* 2007;**23**(13):1061–5. [PubMed: 17985008].

Table 1. Description and Frequencies (Mean) of Variables

Variables	Freq.% (Mean)
General information and History	
Age	(59 ± 12.5)
Sex	
Male	69.1
Female	30.9
BMI	
< 20	2.2
20 - 25	24.7
25 - 30	50
30 - 35	18.6
35 - 40	3.6
> 40	0.9
Symptom duration, y	(0.54 ± 1.68)
Chest pain	88.2
dyspnea	32.4
Smoking	20
Packs/day, y	(3 ± 7.4)
Addiction	15.6
Hypertension	55.2
Diabetes	37.1
Hyperlipidemia	44.5
Heart surgery	2.6
Renal failure	0.6
Liver disease	0.2
Carotid vessel disease	0.5
Peripheral vessel disease	0.1
Cancer	0.2
COPD	0.4
Drugs	
ACE Inh	44.3
B Blocker	68.6
Nitrate	63
Diuretic	12.8
Plavix	12.9
ASA	72.6
Ticlopidine	0.1
Thrombolytic agent	0.4
Hypoglycemic agent	30
Antilipid agent	61.3

Insulin	3.4
Oral Ca Blocker	13.4
Warfarin	1.9
Digoxin	3.8
Physical examination	
Systolic BP	(11.9 ± 0.9)
Diastolic BP	(7.74 ± 0.56)
Heart rate	(74 ± 7.5)
Height	(1.6 ± 0.09)
Weight	(70 ± 13)
Paraclinic data	
Cr, mg/dL	(1.27 ± 1)
Uric acid, mg/dL	(5.7 ± 2.75)
K, mmol/L	(4.35 ± 0.46)
ESR	(19 ± 18.9)
INR	(1.1 ± 0.42)
Cardiomegaly	37.4
Aortic calcification	0.4
Pulmonary hypertension	11.3
Myocardial infarction	3.7
Aortic stenosis	2.6
Aortic regurgitation	17.3
Pericardial effusion	2.3
Aorta aneurysm	1.7
Aneurysm location	
Asce and Trans	0.1
Asce	1.3
Desc	0.2
Trans and Desc	0.1
Trans	0.1
Aorta dissection	1.2
LM stenosis	25
LAD stenosis	60
RCA stenosis	40
Ejection fraction	3
< 30	
30 - 50	31.7
> 50	65.3
Operation information	
CABG	90.7
Number of grafts	(2.8 ± 1.6)
Valve surgery	9.9
Number of valve	

1	9.3
2	2.5
3	0.5
Name	4.4
Aorta	
Aorta and Mitral	1.4
Mitral	4.5
Mitral and Tricuspid	1.1
Other single valve	0.3
Triple valve	0.3
Bental	3.2
Aorta aneurysm	0.6
TOF	0.1
PDA	0.2
ASD	1.7
VSD	0.7
CPB Information	
Type of pump	78.7
Off-pump	
On- pump	20.5
Emergency Convert	0.8
Duration of pump, min	(7.9 ± 32.1)
Post op information	
Duration of hospitalization, d	(9.11 ± 4.56)
Duration of ICU, d	(2.73 ± 2)
Duration of Postop, d	(4.88 ± 3.7)
Number of fresh blood in ICU	(0.2 ± 0.16)
Number of pack FFP in ICU	(0.3 ± 0.27)
Number of pack cell in ICU	(0.6 ± 0.32)
Number of pack Platelet in ICU	(0.1 ± 0.17)
Mortality	2.3