Application of AHP Method to Identify Most Important Predictors for Early Mortality after Coronary Artery Bypass Graft

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Abstract —*despite technological advancements, open-heart operations still carry a risk of mortality and morbidity and it is difficult to decide about appropriate protocols of treatment. To aid in the selection of patients for cardiac surgery, several risk scoring systems have been developed during the last decade. The goal of this study was to identify preoperative determinants associated with surgical mortality in patient who underwent Coronary Artery Bypass Graft to assist cardiac surgeons as a facilitator tool in decision making as well as patient counseling. We performed a literature search from 1980 to January 2013 using the MEDLINE and Science Direct database and assessed the quality of by standardized checklist. Data of the reported predictors of mortality after CABG were extracted and 22 studies met our inclusion criteria. The AHP model was developed to determine the relative importance of risk factors and the K-means clustering to group them into 3 levels. Emergency state, age over 80 years and sever Left Ventricular Ejection Fraction proved to be the most important risk factors for early mortality after CABG and considered as core variables. So, our analysis suggests that prior to this operation, operative mortality can be best predicted by these core predictors. This information to determine appropriate intervention as well as to know predicted chances of postoperative adverse outcomes for better management and monitoring for individual patient is helpful and also, facilitates decision making. We conducted that fuzzy clustering and AHP, as engineering tools, and statistics, as a branch of mathematics, has successfully detected strongest risk factors to predict mortality rate after CABG and showed the power of the engineering tools in health area.*

Key Words — Analytic Hierarchy Process, Clustering Analysis, Risk Factors, Decision Making

I. INTRODUCTION

Cardiac events account for more than half of the deaths after surgery in the United States, and are associated with substantial treatment costs (1).Therefore the need for choosing effective, safe and reliable methods of treatment is felt more (2). Despite technological advancements, open-heart operations still carry a risk of mortality and morbidity and it is difficult to decide about appropriate protocols of treatment. To aid in the selection of patients for cardiac surgery, several risk scoring systems have been developed during the last decades (3). Risk models play important roles in modern clinical practice. Their importance involves several aspects: First, a patient's predicted risk is of interest to surgeons to facilitate individual patient counseling or as a decision support tool and one of the factors for clinicians in determining whether a specific surgery is the appropriate intervention (4). Furthermore surgeons need to know which patients should be carefully managed and monitored as a function of their predicted chances of adverse outcomes (5). Because outcomes are influenced by patient co morbidities, severity of illness, and treatment effectiveness and these statistical models have become the gold standard for tracking postoperative adverse events rates (6),(7). So in this aspect, Risk stratification models are critical to clarify criteria for patient selection, resource allocation and improving care (8). Second, risk scores are of interest to hospitals and quality assurance or quality assessment experts (5), Because Risk stratification is an essential element of quality assurance(9). These models have been used in northern New England (10) And Minnesota (11) And by CASS (Coronary Artery Surgery Study) group as the basis for confidential continuous quality improvement activities, and by CICSS group in the Veterans Affairs Administration for both confidential monitoring of performance and continuous quality improvement (12),(13). Third, Risk models have been used for academic research typically to assess and estimation of the effect of risk factors or particular therapies on patient outcome (12). Studies of preoperative risk factors derived from different databases include clarifying the age-specific risks affecting the short-term outcome after isolated coronary artery bypass grafting (CABG) according to JACVSD (Japan Adult Cardiovascular Surgery Database) (14), the impact of gender on operative mortality after CABG surgery registered by CCOPR (California Coronary Artery Bypass Grafting Outcomes Reporting Program) (15) And another study derived from STS NCD and ACC/AHA guidelines. Without risk stratification, surgeons and hospitals treating high-risk patients will appear to have worse results than others. This may prejudice referral patterns, affect the allocation of resources and even discourage the treatment of high-risk patients. This is especially undesirable in cardiac surgery because it is precisely this group of patients which stands to gain most from surgical treatment, in spite of the increased risk (16). Coronary artery bypass graft (CABG) which is a treatment for patients who have narrowing or blockages in their coronary arteries is the most common type of open-heart surgery in the world, owing to improvements in surgical techniques, medications and patient care and it accounts for a significant portion of the total health care expenditure as well as more resources expended in cardiovascular medicine than any other single procedure (17),(18). Therefore most of the methods developed to stratify cardiac risk were focused on this kind of surgery (19), (20).

The goal of this study was to identify preoperative determinants associated with surgical mortality in patient who underwent CABG. The proposed method combines the analytic hierarchy process and clustering method for assessing the statistical data identified in different risk scoring models to weight and classifies early mortality risk factors for CABG. To the best of our knowledge, this is the first study that has used a mathematical method, AHP, to study most important predictors of early mortality after CABG and the problem with its specific characteristics is not reported in the literature.

II. Materials & Methods

This section covers the details regarding preparation of your manuscript for submission, the submission procedure, review process and copyright information.

A. Search Strategy

We performed a literature search from 1980 to January 2013 using the MEDLINE and Science Direct database because of comprehensive nature of these databases. Language restriction was enforced and non–English-language articles were not translated. The reference lists of all selected publications were checked to retrieve relevant publications which had not been found with the computerized search. The search string is shown in Appendix 1.

B. Study Selection

In the first step of screening the articles, only studies that developed a new scoring model were considered. For this research, it was required that studies report on risk models to be used to estimate the risk of operative death for isolated CABG procedures. After review of the title alone or the abstract, we excluded studies have developed prediction model for in-hospital mortality as well as morbidity following valve surgery (include aortic, mitral, Tricuspid and multiple valve surgery), Surgery on thoracic aorta, Heart Transplantation and other less common cardiac procedures. In addition to, the risk stratification models that were developed for predicting extended length of stay in ICU or hospital were not considered. For duplicate publications, only the most recent or most complete report was included. Sometime we considered several version of scoring model because of difference models presented by them.

The remaining 22 articles were reviewed in detail, and finally, a publication was selected for next analysis when it fulfilled the selection criteria include: The studies focused on early mortality as an outcome, CABG surgery, either with or without concomitant procedure as a procedure, Prevalence of patients undergoing CABG was reported more than 60%, exclusively focused on adults, was published in English, and the association (ORs , coefficient or score with corresponding p-value or 95% CI) of predictor factors with the outcome had to be presented. More information of selected papers is summarized in Table 1.

TABLE 1
Summary of selected risk scoring models

SC*	Reference	Region	No. Of Patient	No. Of Center
1	Bayesian-logit model (13)	USA	12712	43
2	CICSS Model (21)	USA	10197	43
3	Sadeghi et al(20)	Iran	504	1
4	QMMI Model (22)	USA	9498	12
5	EuroSCORE (add.)(23)	Europe	13302	128
6	JACVSD Model (24)	Japan	7133	97
7	Pitkanen et al (8)	finland	5413	1
8	Tuman et al (25)	USA	3156	1
9	Torento I (26)	Canada	6213	9
10	NNE I (27)	UK	3055	5
11	NYS (28)	USA	18814	33
12	Amphiascore (29)	Netherlands	7282	1
13	Toronto II (4)	Canada	7491	2
14	NYS II (5)	USA	16120	1
15	Carosella et al (30)	Argentina	4698	4
16	NYS III (31)	USA	10148	1
17	Zheng et al (32)	China	9838	17
18	THIScore (33)	USA	5281	1
19	STS (12)	USA	138762	374
20	Magovern et al (18)	USA	1567	1
21	ACC/AHA (17)	USA	7290	1
22	AusSCORE (34)	Australia	7709	1

**SC: Scoring Code*

C. Appraisal of study design

The study quality of each publication was evaluated by use of standard assessment checklist which is a modified version of the checklists by [21] and [22]. The checklist, developed base on theoretical considerations and methodological aspects, comprises 5 categories, study population, treatment, outcome, prognostic factors and data presentation, and includes items on validity, precision of method and clinical aspect of study design. Follow up was not considered in the checklist because early mortality was defined as outcome type. Taking into account the characteristics of the study “response rate” removed of checklist. The checklist and some additional explanation are provided at Appendix 1. The criteria can be scored positive (‘+’), negative (‘-’) or ‘unclear (‘?’). A positive score indicates sufficient information and a positive assessment. A negative score indicates sufficient information, but potential bias due to inadequate design or conduct. If an item is scored as ‘unclear’ it means that the paper provides insufficient information about this criterion [22].

Two reviewers independently assessed the methodological quality of selected papers and they were blinded to each other’s findings. When disagreement is occurred, reviewer discussed during a consensus meeting and in persistent disagreement, the third reviewer adjudicated the disagreement to determine the final decision. The results of the quality assessment are presented in Table2.

The positive scores on each item (A-M) were summed, with a range from 6 to 12 point and a medium score of 9 point and the result are attributed to study quality score.

D. Data Collection

To facilitate interpretation and comparison of the results, a computerized database was prepared. Data extracted of the prognostic studies including information about scoring systems (study population number and related characteristics, start and end time of data collection, Year of publication), outcome measures, the type of procedure, measure of C-index and multivariate association calculated between predictor factors and outcome in terms of Odds Ratios (OR) with 95% confidence intervals (CI). As mentioned earlier, the endpoint of the present review was early mortality, i.e. 30-days (operative) mortality or hospital mortality(35),(36) And coronary Artery bypass graft, either with or without concomitant procedure, is considered as procedure type. Intra and post-operative surgical characteristics were not considered in the analysis.

The risk factors (RFs) of predefined outcome is categorized as patient demographics includes modifiable and non-modifiable variable, Current status ,past medical history, operative details, previous CV interventions, Medicine , Para clinic Data and functional class. They include the following subcategories: Modifiable variables refer to smoking, addiction and alcohol status information, weight, Obesity, physical activity and body Mass Index. Age, gender, height, body surface area, ethnicity and family history of heart disease are non- modifiable variables. Past medical history include illness in different groups such as cardiac disease, vascular disease and cerebrovascular disease as well as comorbidities such as diabetes mellitus, chronic obstructive pulmonary disease and so on. Operative details include priority of care (elective, emergent or salvage and urgent procedure), and first time versus repeat operation (redo surgery). PTCA and use of IABP was considered in “Previous CV intervention” category and “functional class” were covered Townsend deprivation Score, NYHA and CCS class.

E. Risk factor definition

Consistency in the definition of clinical risk factors and cardiac outcome for being more successful in comparison and interpretation of results is necessary. Unfortunately, Risk factor definition has varied between derivation studies and there is not a clear consensus definition of these variables. Therefore we sometimes had to create categorical variable to cover different definition in our study or exclude variables with very different definition. If the definition presented by studies fall into these categories, we considered it in the analysis otherwise were excluded. The following are the definition of categorical and excluded variable is considered in our study.

- Myocardial Infraction (MI)

Myocardial infraction categorized in three groups: (1) Acute MI (defined as at least one documented MI, 7 days or less before the examination), (2) Recent MI (more than 7 days but 1 month or less before the examination), (3) The traditional intervals includes Lower than 3 month or 3-6 month. This definition reflects the consensus of the ACC Cardiovascular Database Committee [24].

- Renal Failure

Preexisting renal disease has been identified as a risk factor. This factor is defined by elevated serum Creatinine level or patient requiring dialysis. For comprehensive interpretation, Preoperative serum Creatinine levels categorized in four groups: 1.5-2 “mg/dL”, 2-2.5 “mg/dL”, 2.5-3 “mg/dL”and 3 “mg/dL”or greater.

- Left Ventricular Ejection Fraction (LVEF)

There are the same statistically compelling reasons to classify Ejection Fraction (EF) level into categories as has been done in the classification of renal dysfunction. According to American Society of Echocardiography’s Guidelines for Chamber Quantification [25], values of left ventricular function are partitioned to four levels: (1) Reference range: more than 55%, (2) Mildly abnormal: between 45% to 54%, (3) Moderately abnormal: between 30% to 44%, (4) Severely abnormal: less than 30%. Every possible value reported by different studies was included in these partitions and the decision was made to substitute “severely abnormal” for unknown EF definition. By doing so, we could reach higher accuracy in the range of very different EF values. This gives a standardized assessment of this risk factor.

F. Data analysis

THE ANALYTICAL HIERARCHY PROCESS

A variety of decision making methods and tools are available to support health care and medical decision making. Analytical Hierarchy Process (AHP) is a proven decision-making methodology that has seen widespread applications across numerous fields in health. Liberatore and Nydick identified a substantial body of literature that applies the AHP to health care and medical decision making problems [26]. Besides, The AHP appears to be well suited for determining weight of factors or criteria. For example [27] Using an analytical approach, proposed the weight for the three causal factors of obesity based on the three types of obesity and illustrated the usefulness of this method. AHP uses a process of pair wise comparison to determine the relative importance of alternatives in decision making. The pairwise comparisons are organized into a matrix and several methods have been suggested for synthesizing the set of pairwise comparisons to obtain a vector of factors weights. After that, a weighted averaging approach is used to combine the results across levels of the hierarchy to compute a final weight for each factor [26]. Taking into consideration the purpose and method of this study, criteria and factors were identified. The risk scoring models, listed in TABLE 1, were the criteria in this decision model while the significant risk factors of mortality after CABG, mentioned in related model, such as age, gender, poor LVEF and so on were the alternatives.

Step 1: Construct the Pairwise Matrix

Adjusted odd ratios of risk factors calculated by scoring models are pairwise compared in terms of their ability to achieve the goal. Assuming m risk factors and n scoring models, the pairwise comparison of factor i with factor j yields a square matrix $A_{(m*m)}$ for h^{th} model , where, a_{ij} denotes the comparative importance of risk factor i with respect to risk factor j. The matrix can be denoted by:

$$\boldsymbol{A^h} = \left[\left(a_{ij}\right)_{m\times m}\right]^h \quad i, j = 1,\dots,m \ ; h = 1,\dots,n$$

Where $a_{ij} = 1$: if $i = j$ and $a_{ij} = 1/a_{ji}$, if $i > j$

Step 2: Compute the normalized comparison value of risk factor i to factor j

The normalized value of each risk factor is found by calculating the sum of the i^{th} row (or column) and dividing each entry by related summation (S_i). The calculated matrix can be denoted by:

$$\boldsymbol{R^h} = \left[\left(r_{ij}\right)_{m\times m}\right]^h \quad i, j = 1,\dots,m \ ; h = 1,\dots,n$$

Where $\boldsymbol{r_{ij}} = \boldsymbol{a_{ij}}/\boldsymbol{S_j}$ **:** $i, j : 1,\dots,m$, $\boldsymbol{S_j} = \sum_{\boldsymbol{i}=1}^{\boldsymbol{m}} \boldsymbol{a_{ij}}$

Step3: Compute relative normalized weight of each risk factor

The matrix attributed to Normalized weight of each risk factor is denoted by:

$$\boldsymbol{W^h} = \left[\left(W_i\right)_{m\times 1}\right]^h \quad i : 1,\dots,m \ ; h = 1,\dots,n$$

$$W_i = \left(\sum_{j=1}^{m} r_{ij}\right)/m \quad i : 1,\dots,m$$

Step 4: Combine the weights derived in step 3 and the weight of risk scoring models to obtain overall rate

Finally, we compute the overall composite weight of each risk factor based on the weight of each scoring models. The overall weight, P_i, is just normalization of linear combination between adjusted weight, W_i, for each risk factor calculated in step 3 and the normalized weight of scoring model, K_h , developed based on appraisal results. (See section “Appraisal of study design”).

$$P_i = \sum_{h=1}^{n} W_i^h * K_h \quad i : 1,\dots,m$$

C-MEANS CLUSTERING METHOD

The objective of cluster analysis is the classification of objects according to similarities among them, and organizing of data into groups. Several clustering techniques are well known: k-means clustering, fuzzy C–means clustering, mountain clustering and subtractive clustering (SC) method, which is a non-iterative algorithm. Fuzzy clustering methods such as C-means allow objects to belong to several clusters simultaneously, with different degrees of membership.

In this study, we proposed fuzzy C-means (FCM) clustering to classify the results analyzed by AHP method, W_i , into 3 levels (core, level 1and level 2) in order to reflect their importance for prediction of early mortality after CABG. This algorithm focuses on minimizing the function which is calculated weighted within-group sum of squared errors, J_p, Subject to several constraints as follow:

$$Min \quad J_p = \sum_{i=1}^{m}\sum_{j=1}^{c} u_{ij}^p \left\| W_i - C_j \right\|^2$$

$$\text{s.t: } \sum_{j=1}^{c} u_{ij} = 1 \ , i = 1,\dots,m$$

$$0 < \sum_{i=1}^{m} u_{ij} < m \quad , j = 1,\dots,c$$

$$\text{Where } u_{ij} = 1 / \sum_{k=1}^{c} \left(\left\| W_i - C_j \right\| / \left\| W_i - C_k \right\| \right)^{2/m-1}$$

$$C_j = \sum_{i=1}^{m} u_{ij}^p . W_i \Big/ \sum_{i=1}^{m} u_{ij}^p$$

In Equations, m and c are the number of samples and clusters respectively. p is a real-valued number to control fuzziness or amount of cluster overlap. u_{ij} , is the degree of membership of i^{th} sample, W_i, belonging to j^{th} cluster (C_j); the matrix of membership function denoted by: $U = [\left(u_{ij}\right)_{m\times c}]$.

The algorithm is carried out through an iterative optimization of the objective function with the update of membership matrix and the cluster centers. The iteration will stop until the maximum number of iterations is reached or stabilization, i.e. or $\left\| U^{(k+1)} - U^k \right\| < \varepsilon$, where ε is a Stopping criterion between 0 and 1, whereas k is the iteration steps (37);(38). Computations of C-means method were carried out in R software version (2.15.2) using package “e1701-1.6-1”. Moreover, the results of clustering and AHP method are tabulated in TABLE 3, 4 AND 5.

III. RESULT

As mentioned earlier, important risk factors clustered in 3 levels. TABLE 3, 4 and 5 summarizes a list of risk factors considered as core, level1 and level 2 variables respectively.

Emergency state, age over 80 years and sever LVEF proved to be the most important risk factors for early mortality after CABG and considered as core variables. Level1 variables were concluded to be of less prognostic importance than core variable. Our results showed that Prognostic factors such as Diabetes Mellitus, NYHA class (IV, III), Congestive Heart Failure (CHF), arrhythmia and other variables mentioned in TABLE 5 were not quite as important in predicting short term mortality for patients undergoing CABG as core and level1variables. Some prognostic factors for example Blood urea nitrogen, serum albumin , anemia (18), long term corticosteroids (39), aortic valve stenosis (24), infective endocarditis (23), Intravenous nitroglycerine use (21) and Left ventricular end-diastolic pressure (10) were only reported once or twice. Hence, the evidence on their predictive value remains inconclusive.

IV. DISCUSSION

The aim of this study was to identify most important variables which can help to predict operative mortality before performing the CABG surgery. Our analysis suggests that prior to this operation, operative mortality can be best predicted by sever LVEF, advanced age and emergent surgeries. Although several scoring model were developed to predict mortality after CABG, few published studies have developed to define and prioritize the importance of related risk factors.

The Working Group Panel on the Collaborative CABG Database Project has categorized 44 clinical variables into 7 core, 13 level1 and 24 level 2 variables, to reflect their relative importance in determining short-term mortality after CABG. This group has identified and proposed uniform definitions for a list of 7 core variables (i.e., age, gender, acuity of operation, LVEF, previous operation, left main coronary artery disease and number of diseased coronary arteries) that they consider must be present in any database of patients undergoing CABG (40). Similarly, Tu and associates have suggested a limited set of six core variables (age, gender, emergency operation, previous CABG or redo surgery, LVEF and left main disease) appear to be sufficient for fairly comparing hospital risk-adjusted mortality rates after CABG in Ontario (26). Moreover, these researchers as well as Hannan and associates believed that left ventricular ejection fraction, reoperation, and left main disease have an important impact on hospital risk-adjusted mortality rates and that these factors should be part of any risk adjustment model for assessing the short-term results of CABG (26),(41).

The ACC/AHA guidelines for CABG surgery summarize that greatest risk of mortality after CABG is correlated with advancing age, one or more prior coronary bypass operation, and urgency of operation (17).

Likewise, Ranucci and associates included ejection fraction, serum creatinine and age were highly statistically significant predictors of early mortality after CABG for elective patient and the model limited to these predictor had an accuracy equivalent to or better compared with more complex risk scores (42). Therefore, our results do not conflict with presented work and also suggests that the factors lists in TABLE 3 have an important impact on early mortality rates for patient undergoing CABG in different regions and these factors should be part of any risk stratification models.

TABLE 3

CORE RISK FACTORS (NUMBER(S) IN PARENTHESES SHOW THE SCORING CODE)

Core Risk Factors	Weight
Emergent surgery (3-10,12-15,17-21)	0.097
Severely LVEF* (3-16,19-22)	0.064
Age>85 (2,4-16,18-22)	0.064
Age 80-85 (2,4-16,18-22)	0.058

***** *LVEF* (Left Ventricular Ejection Fraction)

TABLE 4

LEVEL1 RISK FACTORS (NUMBER(S) IN PARENTHESES SHOW THE SCORING CODE)

Level 1 Risk Factors	Weight
Age 75-80 (2,4-16,18-22)	0.046
Age 70-75 (2,4-16,18-22)	0.045
Re-operation-first (2,4,5,9-15,18-21)	0.044
History of cardiogenic shock (4,6,11,14,17,19,20)	0.040
Cr *>3 (4-8,12,16-18,21,22)	0.039
Cr :2.5-3 (4-8,11,12,16-18,20,21)	0.036
Age 65-70 (2,4-16,18-22)	0.033
Emergent salvage (6,15,19,22)	0.030
Cr :2-2.5 (4-8,12,16-18,20,21)	0.029
Dialysis Depended (6,11,14,16,18-21)	0.027
Urgent Surgery (4,5,6,9,10,15,17-22)	0.025
Female (4-16,18-21)	0.023
Age 60-65 (2,4-16,18-22)	0.023
COPD *(4,5,6,11,14,17-21)	0.020
LVEF-moderate (4,5,9,10,11,13-16,22)	0.019
AMI *(12,14,16,21)	0.019
PVD * (2,5,6,13-16,19-22)	0.019
Liver Disease (4,11)	0.018

* *Cr* (Serum Creatinin), *COPD* (Chronic Obstructive Pulmonary Ejection Fraction), *AMI* (Acute Myocardial Infraction), *PVD (*Peripheral Vascular Disease)

TABLE 5

LEVEL2 RISK FACTORS (NUMBER(S) IN PARENTHESES SHOW THE SCORING CODE)

Level 2 Risk Factors	Weight
IABP* (2,15,1719)	0.014
Hemodynamically unstable (11,14,16,19)	0.013
NYHA* class IV (7,17,19,22)	0.012
Arrhythmia (6,11,17,19,20)	0.010
Diseased Vessel III (10,13,15,18-21)	0.010
NYHA class III (2,17,22)	0.010
Cr :1.5-2 (4,6,8,19,20)	0.009
CHF* (5,6,8,18,20)	0.009
DM* (7,11,19,21)	0.008
Stroke (4,8,11,19,20)	0.007
Re-operation-multiple (18,19)	0.007
Recent MI (2,16,19)	0.006
LMCS* (10,13,19,21)	0.005
Mildly LVEF (9,10,13)	0.005
MI <3 , or 3-6 month (5,8)	0.004
LVH* (2,20)	0.004
Inotropes (6,19)	0.004
Aortic Valve Stenosis (6)	0.003
Calcified Ascending Aorta (11,14)	0.003
Insulin Depended (15,20)	0.003
Hypertension (4,13)	0.003
Diseased Vessel II (10,15)	0.003
Infective Endocarditis (5)	0.003
Ethnicity (19)	0.002
Neurological Dysfunction (5)	0.002
LVEDP* (10)	0.002
Intra Venous Nitroglycerin (2)	0.002
Diseased Vessel I (10,15)	0.002
Smoking (6)	0.002
Unstable Angina (5)	0.002
Digitals(19)	0.001
Systolic Dysfunction (19)	0.001
Long Term Corticosteroids(19)	0.001
Diuretics (19)	0.001
Semi Urgent Surgery(13)	0.001
Anemia(20)	0.001
Blood urea nitrogen (20)	0.001
Non-Insulin Depended(20)	0.001
Serum Albumin(20)	0.001

**IABP (*Intra-Aortic Balloon Pump), *NYHA* (New York Heart Association), *CHF (*Congestive Heart Failure), *DM (Diabetes Mellitus), LMCS* (Left Main Coronary Stenosis), *LVH* (Left Ventricular Hypertrophy), LVEDP (Left Ventricular End-Diastolic Pressure)

V. CONCLUSION

We conducted that fuzzy clustering and AHP, as engineering tools, and statistics, as a branch of mathematics, has successfully detected strongest risk factors to predict mortality rate after CABG and showed the power of the engineering tools in health area. This preliminary research need to be extended by considering geographical characteristics. This study could also be extended to weight identified risk factors of CABG morbidity or extended length of stay in ICU or hospital. In addition to, predictors of adverse outcome following valve surgery (include aortic, mitral, Tricuspid and multiple valve surgery), Surgery on thoracic aorta, Heart Transplantation or cardiac intervention such as PCI can be prioritized in the same way.

APPENDIX

APPENDX1

SEARCH STRING TO SCREEN POTENTIAL ARTICLES RELATED TO OUR RESEARCH

["risk assessment" OR "risk assess*" OR "risk function*" OR "risk equation*" OR "Risk Calc*" OR "Risk Scor*" OR "Risk Predict*" OR "Risk Factor Calc*" OR "Risk Chart*" OR "Risk Engine*" OR "Risk Appraisal*" OR "Prediction Model*" OR "Risk algorithm" OR "Scoring* Method*" OR "Scoring Scheme*"] AND ["cardiovascular disease*" OR "coronary disease" OR "heart diseases" OR "cardiac"] AND [Surgery] AND [Death OR mortality] AND [Coronary artery bypass].

APPENDIX 2

CRITERIA LIST FOR ASSESSING THE METHODOLOGICAL QUALITY OF PROGNOSTIC STUDIES

Criteria		
Study population:		
A	Description of inclusion and exclusion criteria	Positive if at least the following were included: age, period of study, type of study population.
B	Description of domain of study population	Positive if patient source was described.
C	Has been validated in different regions?	
Treatment:		
D	Clear definition of procedure	Positive if surgical procedures is fully described or standardized
Outcome:		
E	Clear definition of outcome	Positive if outcome type is fully described or standardized
Prognostic Factors		
F		Clear definition of predictors (at least 80%)
Data presentation:		
G	Frequencies of most important outcome measures	Positive if frequency, percentage ,mean or median for Outcome measured was reported
H	Frequencies of most important factorsmeasures	Positive if frequency, percentage ,mean or median for significant predictors was reported
I	Positive if standard deviation /CI (confidence interval) of (OR) for significant predictors were reported	
J	Appropriate performance techniques	Positive if appropriate test for assessing calibration (discrimination of model was used.
K	The discriminatory ability of model	Positive if ROC measure>80%
L		Positive if prevalence of patients undergoing CABG without concomitant procedure was reported 100%
M	Sufficient numbers	Positive if the number of cases in the multivariate analysis was at least ten times the number of independent variables in the nalysis

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