A predictive model for prediction of heart surgery procedure

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ABSTRACT
Coronary heart disease (CHD) is a disease in which plaque in the form of waxy substance builds up inside the coronary arteries. Coronary artery bypass grafting (CABG) is used as treatment on CHD patients but the role of CABG has been challenged by percutaneous coronary intervention (PCI) when it was introduced in 1977. Drug eluting stents (DES) was introduced with the development of PCI. The purpose of this study was to find the potential risk factors that associated with the procedures (CABG and DES) and to model procedure (CABG vs DES) on coronary heart disease male patients aged 45 years old and below. The study sample was among male patients aged 45 years old and below who has undergone CABG or DES procedure at either IJN or HUKM from January 2007 until December 2010. Logistic regression was used to model treatment selection on coronary heart disease with 87.3% of the classification rate. Patient who i) smoke, ii) obese, or ii) had dyslipidemia was significantly associated with DES, and the other factors were prone to have CABG as their treatment.

1. INTRODUCTION
Coronary heart disease (CHD) is a disease in which plaque in the form of waxy substance builds up inside the coronary arteries, whereby oxygen-rich blood will be supplied to heart muscle by these arteries [1]. The plaque can break open (rupture) or hardened over time. If ones suffer with ruptured plaque, the blood clot will be formed on its surfaces and this can disturb the blood flow through coronary artery. Nevertheless, the hardened plaque that is built over time can narrow the artery system and blood flow will be reduced or blocked. If the flow of oxygen-rich blood to heart muscle is not sufficient, angina (chest pain) or heart attack can occur. Ones will feel like pressure or squeezing in the chest or may even feel like indigestion. The pain also can be felt at shoulders, arms, neck or back. Without quick treatments, CHD can lead to serious heart problem like heart failure, in which the heart fails to pump enough blood to meet the body needs. For almost half of century, coronary artery bypass grafting (CABG) has been regarded as the most effective revascularization treatment and become a standard care for CHD patients [2].

However, the role of CABG has been challenged over the last two decades by percutaneous coronary intervention (PCI) when it started to be introduced in 1977. Due to the increasing number of heart disease globally, numerous studies has been conducted that focus on the diagnostic system [3-5]. As up to date numerous studies have been conducted for the purpose of comparing the effectiveness of PCI with CABG.
However, lacks of studies have been conducted to determine which risk factor is associated with the use of suitable procedure in order to treat CHD. Therefore, the purpose of this study is to identify the important risk factor for the selection of CABG or drug eluting stents (DES) procedure among young patients specifically less than 45 years old.

1.1. Factors related to Selection of Procedure

Generally, the selection of suitable procedures (CABG or DES) to cure CHD depends on lifestyle profile, the types of comorbidities (such as diabetes melitus, chronic obstructive pulmonary disease, atrial fibrillation, renal impairment) and the number of vessel disease suffered by patients. For instance, Mavromatis et al. [9] in their study stated that coronary CABG is found to be more effective over PCI in improving the mortality in patients with diabetes and three-vessel coronary artery disease who were not at high surgical risk. The finding is similar with a study conducted by Nystrom et al. [10] where CABG as a preferred strategy for patients with Type 1 Diabetes in need of multivessel revascularization.

The safety and efficacy of DES in older patients with chronic kidney disease (CKD) is measured by Tsai et al. [11] and it was found that there was a significant reduction in mortality, myocardial infarction and revascularization. The recent study by Lu et al. [12] also reported that the condition of CKD patients are significantly improved with DES, however large-sized randomized controlled trials were necessary to determine the real effect on CKD patients and whether efficacy differs by type of DES.

With regards to atrial fibrillation disease, Ruiz-Nodar et al. [13] had revealed the effectiveness of DES was not in the long run as many problems arose such as high rate major bleeding, higher rate of stent thrombosis and higher risk of thrombo-ebolism. CABG in other hand also do not show the long term effectiveness when atrial fibrillation remained the most common disease after open surgery and occurred in up to 50% of patients [14].

The development of cardiovascular disease is well associated with obesity when majority of high BMI patients are among the population of CHD. In a study by Johnson et al. [15], overweight and obese patients were benefited with CABG when they had a survival advantage over underweight, normal weight and morbidly obese patients. Psychologically, low BMI patients may not tolerate with the effects of weight loss as compared to obese individuals possibly may lead towards high mortality [16].

2. RESEARCH METHOD

2.1. Sample

This study used a secondary data which was obtained from Division of Cardiothoracic, Hospital Universiti Kebangsaan Malaysia (HUKM) and Institut Jantung Malaysia (IJN). It covered a total of 315 male patients’ record from January 2007 until December 2010. The study sample involved only patients aged 45 years old and below who undergone CABG or DES procedure. Data comprised of demographic profiles, lifestyle profile, co-morbid condition, vessel involvement. The outcomes of procedure were either CABG or DES.

2.2. Binary Logistic Regression

Binary logistic regression model was used in order to model procedure (CABG vs DES) based on associated risk factors. Logistic regression allows one to predict a discrete outcome such as group membership from a set of variables that may be continuous, discrete, dichotomous or a mix of any of these. Generally, binary logistic regression is used when the dependent or response variable is a dichotomous variable such success or failure. The logistic regression model describes the probability of occurrence of the outcome of the dependent variable [17, 18]. The model is designed to describe the probability which is between 0 and 1, whereas in theory continuous variables can take any value between plus or minus infinity [19]. This means that we cannot assume normality for a proportion and we must recognize that proportion have a binomial distribution. The mean and variance of the binomial distribution are not independent. The mean is denoted by \( \pi \) and the variance is denoted by \( \pi(1-\pi)/n \) where \( n \) is the number of observation and \( \pi \) is the probability of the event occurring in any one trial.

Let:

\[ \pi_i = Pr(Y=1|X = x_i) \]

The logistic regression model:
\[ \log \left( \frac{\pi_i}{1-\pi_i} \right) = \beta_0 + \beta_1 \cdot \text{gender} + \beta_2 \cdot \text{race} + \beta_3 \cdot \text{smoking} + \beta_4 \cdot \text{obese} + \beta_5 \cdot \text{dyslipidemia} + \beta_6 \cdot \text{Diabetes} + \beta_7 \cdot \text{Atrial Fibrillation} + \beta_8 \cdot \text{Hypertension} + \beta_9 \cdot \text{Unstable Angina} + \beta_{10} \cdot \text{Dyslipidemia} + \beta_{11} \cdot \text{Left Anterior Descending} + \beta_{12} \cdot \text{Left Circumflex} + \beta_{13} \cdot \text{Right Coronary Artery} \]

where
\[ \pi_i = \text{Probability of having CABG as heart treatment option} \]
\[ 1 - \pi_i = \text{Probability of having DES as heart treatment option} \]
\[ x_i = \text{Risk factors of complication during surgery} \]
\[ \beta_k = \text{Coefficient of parameter} \]

3. RESULTS AND DISCUSSION

3.1. Respondent Profile

In general, background of male patients are studied which include demographic profile, lifestyle profile, the other disease that they had at the same time (co-morbid condition), and the heart vessel that was affected from heart disease (vessel involvement). As regard to ethnicity, the disease being most common among the Indian population (Table 1). Based on the estimated population of Malaysia [20], coronary heart disease incidence among the Malay and Chinese populations are still considerably lower by 10.9% and 12.2%, respectively. However, for the Indian population the incidence of coronary heart disease was high at 23.8%. Further, the distribution of smokers and non-smokers was quite balanced with 50.8% and 49.2%, respectively. However, only 13.3% male patients face with obesity issue while 86.7% patients do not have the particular issue.

| Ethnic Group | Estimated Population | Patients Diagnosed with CHD | Difference |
|--------------|----------------------|-----------------------------|------------|
| Malay        | 67.4%                | 56.5%                       | 10.9%      |
| Chinese      | 24.6%                | 12.4%                       | 12.2%      |
| Indian       | 7.3%                 | 31.1%                       | 23.8%      |
| Others       | 0.7%                 | -                           | -          |

*Source: Department of Statistics Malaysia, 2010

3.2. Test of Association

The two-way association was attempted to measure the association between variables of each category (lifestyle profile, co-morbid condition and vessel involvement) with the selection of procedure. The odds ratio for variables that indicate significant association was then measured to quantify how strong the absence or presence of risk factors is associated with the presence or absence of procedure (CABG or DES). With reference to lifestyle profile, both variables (smoking and obesity) had a significant association with the procedure. Among all variables which fall under co-morbid condition category, only dyslipidemia and diabetes had an association with the selection procedure. In other hand, vessel involvement category shows association with the procedure when p-value for left anterior descending (LAD), left circumflex (LCX) and right coronary artery (RCA) were less than 0.05 which indicated significant results. With reference to odd ratio estimates, patient who smoked, obese or having dyslipidemia was more likely to be in DES group meanwhile diabetes, LAD, LCX and RCA belong to CABG procedure.

3.3. Binary Logistic Regression

The best model development starts with measuring its performance using several statistical tests after confirming the dataset has no indication of outliers and multicollinearity. Table 2 shows the Omnibus Tests of Model Coefficient to measure the performance of logistic regression model. Based on the analysis, it was concluded that at least one of predictors was significant in order to predict the suitable procedure of treating coronary heart disease when the significant value is less than 0.10

| Chi-square | Degree of freedom | Sig.   |
|------------|------------------|--------|
| Model      | 250.102          | 10     | 0.000  |

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The proportion of variation in the response variable by predictors is determined by Cox & Snell R-Square and Nagelkerke R-Square in Table 3. The model was better when the value was closer to one. Therefore, the selection of procedure is explained by predictors about 54.7% to 73.2%.

### Table 3. Variation of Response

| Step       | -2 Log likelihood | Cox & Snell R Square | Nagelkerke R Square |
|------------|-------------------|----------------------|---------------------|
| 1.         | 182.684            | 0.584                | 0.734               |

The Hosmer and Lemeshow goodness-of-fit statistic assessed how well the logistic regression model fits the data. Based on the analysis as displayed on Table 4, it was concluded that the model fits the data very well since the significant value was greater than 0.05.

### Table 4. Hosmer and Lemeshow Test

| Chi-square | Df | Sig. |
|------------|----|------|
| 3.20       | 8  | 0.921|

Classification table in Table 5 showed the percentage of correct classification of dependent variable (CABG vs DES) as well as measuring the error rate. The performance of the model also can be predicted by error rate by measuring the proportion of misclassified observation. As illustrated in the same table, the data was correctly classified by 87.3% and the error rate was 12.7%. Hence, it showed that this model could classify accurately the observed and predicted of procedure.

### Table 5. Classification Table

| Procedure   | Observed | Predicted | % correct |
|-------------|----------|-----------|-----------|
| Procedure   | CABG     | DES       |           |
| CABG        | 121      | 19        | 86.4      |
| DES         | 21       | 54        | 88.0      |
| Overall Percentage | 45.1 | 54.9 | 87.3 |

Table 6 shows the parameter estimates, standard error, Wald statistics, degree of freedom, significant value and odds ratio (Exp B) of full model (included all predictors). Among variables that have been evaluated, there were seven significant variables in predicting the suitable procedure for treating CHD which included smoking, obesity, dyslipidemia, diabetes, LAD, LCX and RCA. The final estimated logistic regression as follows.

### Table 6. Variables of Estimated Model

| Variables              | B     | S.E. | Wald   | df | Sig. | Exp(B) |
|------------------------|-------|------|--------|----|------|--------|
| Smoking(1)             | -1.942 | 0.420 | 21.377 | 1  | 0.000 | 0.143  |
| Dyslipidemia(1)        | -2.248 | 0.429 | 27.428 | 1  | 0.000 | 0.106  |
| Pulmonary Hypertension(1)| 0.137  | 0.409 | .112   | 1  | 0.738 | 1.147  |
| Diabetes_Melitus(1)    | 0.854  | 0.408 | 4.369  | 1  | 0.037 | 2.348  |
| Obesity(1)             | -2.941 | 0.655 | 12.275 | 1  | 0.000 | 0.101  |
| Unstable Angina(1)     | 0.084  | 0.756 | 0.012  | 1  | 0.912 | 1.087  |
| Atrial Fibrillation(1) | 0.992  | 1.107 | 0.803  | 1  | 0.370 | 2.696  |
| Left Anterior Desceding(1)| 3.421  | 0.518 | 43.575 | 1  | 0.000 | 30.585 |
| Left Circumflex(1)     | 2.693  | 0.449 | 35.930 | 1  | 0.000 | 14.778 |
| Right Coronary Artery(1)| 1.791  | 0.440 | 16.555 | 1  | 0.000 | 5.993  |
| Constant               | -3.771 | 0.701 | 28.923 | 1  | 0.000 | 0.023  |

\[
\log\left( \frac{\pi_i}{1-\pi_i} \right) = -3.771 - 1.942 \times smoking - 2.248 \times dyslipidemia + 0.137 \times Diabetes - 0.294 \times obesity + 3.421 \times LAD + 2.693 \times LCX + 1.791 \times RCA
\]
\[ \pi_i = P(\pi(y) = 1) \]

In summary, with respective to lifestyle profile, smoking and obese patients were more likely to have DES with odds ratio of 6.99 and 9.90 respectively. In term of co-morbid condition, patients with dyslipidemia was 9.43 times more likely to have DES meanwhile patient with diabetes mellitus is 2.35 times more likely to have CABG. As regard to vessel involvement all risk factors (LAD, LCX and RCA) were more likely to have CABG at odd ratio of 30.6, 14.78 and 5.99 respectively.

4. CONCLUSION

This paper intended to add knowledge of the use of statistics in medical as it allows clinical researchers to draw reasonable inferences based on available information, thus to make a sound decision. Even though, medical practitioners would usually conduct clinical trial to determine the safe and effective procedure for patients [21-23], this paper would beneficial them as a guideline in statistical point of view to select a suitable procedure to cure CHD. CABG or DES is the treatment procedure that commonly used for CHD patients. Binary logistic regression model was used in order to model procedure (CABG vs DES) based on associated risk factors (lifestyle profile, co-morbid condition and vessel disease). From the findings, it clearly justified that binary logistic regression model was appropriate to find the risks factors of disease [24-26], particularly in this study that associated with the selection of either CABG or DES. With the reference to lifestyle, smoking and obese patients were more likely to have DES. In term of co-morbid condition, patients with dyslipidemia were likely to have DES while diabetic patients were prone to have CABG. All risk factors that associated with vessel disease were more likely to have CABG as a heart treatment.

ACKNOWLEDGEMENTS

We would like to express our gratefulness and appreciation to Department of Surgery, UKM Medical Centre for allowing us to use the medical data for the research work. Appreciation to the University Teknologi MARA for financial support under the Grant Scheme 600-IRMI/MyRA 5/3/BESTARI (039/2017)

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