Association of Severe Stenosis in Coronary Arteries with Common Demographic and Clinical Data among Ischemic Heart Disease Patients

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***Abstract*— The number of death due to ischemic heart disease (IHD) keep increasing every year and it is usually caused by coronary artery disease (CAD). Early diagnosis of CAD requires a combination of multiple tests including a 12-lead ECG test, blood test, and stress test before the patient can go through a more complex procedure such as coronary computed tomography angiography or invasive coronary angiography procedure. The study aims to investigate the association between common parameters from the preliminary test of CAD to the severity of stenosis in the coronary arteries among newly diagnosed IHD patients. A total of 80 CAD patients (55 ± 9.52 years) have participated in this study and their demographic data, vital signs, blood tests, as well as ECG result are taken just before they are going for the angiography procedure. It was found that 75% of the subjects are overweight. The results also showed that the number of patients who smoke, have diabetes, and have hypertension is higher in the case group (stenosis ≥ 70%) as compared to the control group (stenosis < 70%). There was no clinical data that can differentiate severe stenosis in the coronary arteries, except for fasting blood sugar (p=0.002). Subjects with severely blocked arteries tend to have higher levels of blood sugar with a mean of 8.05 ± 3.60. Framingham risk scores (FRS) for both groups were also compared, and it is found that 59% of the total subjects have low FRS, even though half of them have severe stenosis. Thus, a technical approach is required to determine the stenosis level in the coronary arteries. The application of non-invasive techniques such as electrocardiogram and photoplethysmogram is preferable for this purpose.**

Keywords*— *clinical data, coronary artery disease, demographic data, severe stenosis

I. Introduction

Ischemic heart disease (IHD) is a type of heart problem caused by narrowed heart arteries. It is usually caused by arteriosclerosis, where blood flow in blood vessels is restricted by the accumulation of fatty deposits or plaque. The narrowing or stenosis of the coronary arteries occurs slowly over a long period. If it is not detected at an early stage, patients with coronary artery disease (CAD) are at high risk of death caused by heart attack [1].

Statistics from World Health Organization (2020) show that IHD remains the number one killer all over the world with an estimated number of deaths are around 16% (8.9 million) in 2019 [2]. In Malaysia, the total number of deaths due to IHD keeps increasing every year and has doubled in 9 years period since 2013. This is shown in Fig.1. The average death in a day also increased from 28 people per day to 59 people per day in the same period [3].

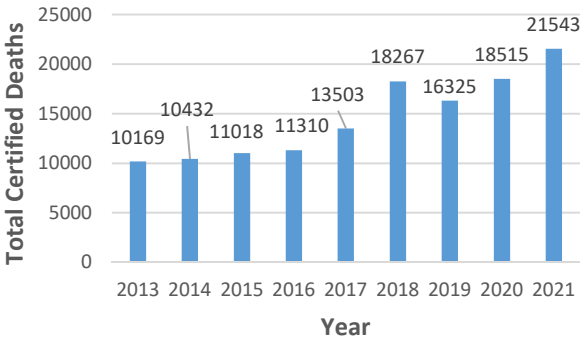

Fig. 1. Total certified deaths due to IHD in Malaysia from 2013 to 2021

Coronary artery disease (CAD) is the most common form of IHD [4]. The arteries can be mild, moderate, and severely blocked. Severely stenosis is categorized when the stenosis level has reached 70% and above [5]. The level is measured using the gold standard method of invasive coronary angiography procedure (ICA) [6]. Besides ICA, coronary computed tomography angiography (CCTA) has become more efficient as a minimally-invasive alternative to pre-diagnose the disease[7]. However, both imaging methods are operationally complex and readily available in Malaysia. Electrocardiography (ECG) tests and exercise stress tests often give inconclusive results [8], [9]

The diagnosis of CAD varies according to the initial evaluation based on symptoms, medical history, clinical information such as blood pressure and lipid profile, as well as CAD risk factors such as smoking status [10], [11]. The ECG test is also included in the list to see any abnormality in heart readings and curve patterns. However, these

preliminary tests do not give accurate information such as the level of blockage, and are only conducted to see whether a patient should undergo specific diagnostic tests such as ICA and CCTA. Thus, this study is conducted to investigate the association of the common demographic and clinical parameters with the severity of stenosis of the coronary arteries.

II. CAD Symptoms and Risk Factors

The symptoms of CAD are chest pain (angina), palpitations, dyspnea, fatigue, weakness, dizziness, nausea, and vomiting. Angina is an important symptom of critical CAD with two conditions, stable and unstable. Stable angina occurs when the patient often feels chest pain while doing activities or experiencing emotional stress. This chest pain is temporary and usually disappears after the patient rests or takes medication [12]. Unstable angina occurs without a particular pattern, and it can occur even when the patient is at rest. This is due to the rupture of plaque deposits or inflammatory mechanisms in the coronary arteries of the heart [13]. In most cases, the symptoms of CAD begin to be seen when the narrowing of the artery has reached 70% of the actual diameter of the artery [14].

In addition to symptoms, medical history and risk factors for CAD should be considered during the initial evaluation of CAD. These include a family history of heart disease, blood lipid profile, diabetes, hypertension, smoking, and lifestyle factors [11]. Age and gender are also important risk factors for this disease. Studies from 2001 to 2013 show that the number of deaths due to CAD in Malaysia for men is higher than for women [15]. From the same study, men can develop CAD as early as their 30s, while women as early as their 40s.

Based on the risk factors that have been explained, many risk calculation models have been built to tell the level of a person's risk of getting heart disease in general. Among the popular risk factor models to determine the level of risk of CAD in 10 years is the Framingham Risk Score (FRS). This model has been validated and recommended in ACC/AHA guidelines on the management of patients with suspected CAD [16]. This FRS model considers the factors of age, gender, systolic blood pressure, total cholesterol, high-density lipoprotein (HDL), hypertension, and smoking status. The FRS model gives different weightage to all seven factors and translates the score differently among male and female individuals [17]. The calculated score is mapped to three risk levels, which are low, medium, and high, as shown in Table I.

TABLE I. The Risk Level for the Framingham Risk Score

Risk Level	Score
Low	Less than 10%
Intermediate	10% to 20%
High	20% and above

III. Methodology

A. Subjects

This is a prospective study where patient data is collected before the angiogram result is known. Data collection was carried out at Hospital Canselor Tuanku Muhriz (HCTM), Universiti Kebangsaan Malaysia (UKM), Cheras, upon the approval of the UKM Research Ethics Committee on March 2021 (UKM PPI/111/8/JEP-2020-806). The convenience sampling method is used where it depends on the attendance and voluntariness of the subject. A total of 130 newly diagnosed CAD elective patients have agreed to volunteer for the study. These patients have been preliminarily diagnosed and categorized in I.24.9 (Acute ischemic heart disease, unspecified), under the 10th edition international code of disease (ICD-10-CM).

B. Selection Criteria

A total of 80 patients aged between 22 years and 65 years (55 ± 9.52 years) were identified as appropriate for this study based on the subject selection criteria, as shown in Table II. Subjects above 65 years old were excluded from participating in this study since the tendency for them to have cardiovascular disease (heart or blood vessel issues) is higher compared to the younger one [18]. Based on the angiogram result, subjects were categorized into the Case group, if they have stenosis 70% or more in at least one major coronary artery.

TABLE II. Subject Selection Criteria for Case and Control Groups

Selection Criteria	Control Group	Case Group
Inclusive Criteria	• Age 21 – 65 years • Stenosis < 70% • An elective patient who has never been diagnosed	• Age 21 – 65 years • Stenosis ≥ 70% • An elective patient who has never been diagnosed
Exclusive Criteria	• Pregnant women • Have chronic diseases such as cancer, kidney problem, etc. • Have different heart diseases other than IHD.	• Pregnant women. • Have chronic diseases such as cancer, kidney problem, etc. • Have different heart diseases other than IHD. • Have undergone heart surgery • Have pacemaker

C. Demographic and Clinical Data

A few demographic and clinical data have been identified based on risk factors as well as previous clinical studies on vital signs and ECG results. The demographic data includes age, sex, family history of heart disease, body mass index, overweight, smoking, hypertension, and diabetes. These data were obtained through questionnaires and patients' medical records in the hospital's information system.

The blood pressure reading of systolic (SBP) and diastolic (DBP) are obtained directly from the patient's bedside monitor, which indicates if the subject has hypertension or not. The glucose level and lipid profile readings which include low-density lipoprotein (LDL), high-density lipoprotein (HDL), total cholesterol (CHOL), and triglycerides (TRIG) are the common clinical variables observed for IHD.

The ECG results are obtained from the hardcopy of tracing paper from the ECG machine. This machine produced unconfirmed-diagnosis for doctors and clinicians from several parameters calculated using the built-in algorithms such as heart rate (HR), PR interval (PR-int), QRS duration (QRS-dur), QT interval (QT-int), and corrected QT interval (QTc-int). However, the PR-int is excluded from this analysis

since there are cases with no values of PR-int due to the low amplitude of the P-wave. In total, there are 20 parameters observed in this study. This is shown in Table III.

TABLE III. PATIENT DEMOGRAPHIC AND CLINICAL DATA

No	Parameter	Data / Range
1	Age	21 – 65 years
2	Sex	Male / Female
3	Body mass index (BMI)	Normal: 18.5 – 24.9
4	Smoking	Yes / No
5	Hypertension	Yes / Mo
6	Diabetes	Yes / No
7	Overweight	Yes / No
8	Family with heart disease	Yes / No
9	SBP - Systolic Blood Pressure	Normal: 90 – 120 mmHg
10	DBP - Diastolic Blood Pressure	Normal: 60 – 80 mmHg
11	MAP – Mean Arterial Pressure	Normal: 70 – 100 mmHg
12	LDL – Low-density Lipoprotein	Normal: < 3.8 mmol/L
13	HDL – High-density Lipoprotein	Normal: 1.55 – 3 mmol/L
14	CHOL – Total Cholesterol	Normal: < 5.2 mmol/L
15	TRIG – Triglycerides	Normal: < 1.7 mmol/L
16	FBS – Fasting Blood Glucose	Normal: 3.9 – 5.5 mmol/L
17	HR – Heart Rate	Normal: 60 – 100 bpm
18	QRS-dur	Normal: < 120 ms
19	QT-int	Normal: 350 – 450 ms
20	QTc-int	Normal: ≤ 460 ms

IV. RESULTS AND DISCUSSION

A total of 40 subjects were selected from each study group and the average age difference between them was 4.125 ± 2.94 years. Exact age matching was difficult as the number of subjects from the Control group involved was limited. Subjects from the Case group had severe coronary artery stenosis, while subjects from the Control group consisted of subjects with three different categories of stenosis. Nevertheless, the number of subjects in each category of stenosis in this group was relatively balanced. A total of 15 subjects had normal arteries, 14 subjects with mild stenosis, and 11 subjects with moderate stenosis.

The selected subjects are from different races, where 75% of them are Malays, 17% are Chinese and the rest are Indians. As for gender, 60 subjects are male. The mean age of subjects from the Control group was 51.58 ± 10.42 years, only four years lower than the Case group (55.70 ± 8.27 years). This data can generally illustrate that Malaysians are at risk of having their first heart attack as early as in their 50s. These statistics are consistent with CAD mortality records in Malaysia, as reviewed in [15]. In terms of body weight, subjects from both study groups were overweight, with BMI above 25. A summary of this information is shown in Table IV.

TABLE IV. GROUP STATISTICS

Data	Control Group	Case Group
Count (N)	40	40
Age (years)	51.58 ± 10.42	55.70 ± 8.27
Gender (M/F)	M = 28, F= 12	M = 32, F = 8
BMI (kg/m^2)	27.75 ± 3.79	27.20 ± 3.93

Fig. 2 shows information related to other CAD risk factors based on the feedback from the questionnaire given to each subject. The number of subjects who smoke, have hypertension and diabetes is more from the Case group than the Control group. This indirectly shows that the Case subjects who smoke and have hypertension and diabetes are more likely to have severe coronary artery stenosis than the Control subjects since these three factors are among the main risk factors for CAD [11]. In terms of body weight, 75% of the study subjects were overweight, with 30 subjects in each group. Genetic factors are seen to have less impact on the level of coronary artery stenosis.

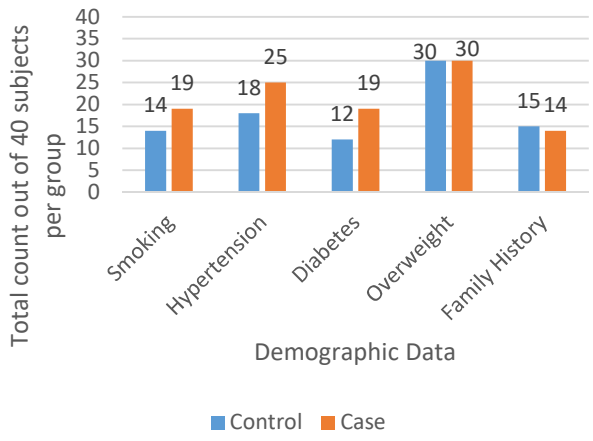

Fig. 2. Comparison of CAD risk factors between the two study groups

The clinical data of the patients were reviewed in terms of the mean value (μ) and standard deviation (σ) for comparison, as listed in Table V. The blood pressure values of the Case subjects were slightly higher than those of the Control subjects, but it did not show a statistically significant difference. Even though SBP is known as one of the risk factors for CAD, there are other factors that can contribute to high blood pressure as well, such as obesity where 75% of the subjects are overweight.

TABLE V. COMPARISON OF CLINICAL DATA FROM TWO STUDY GROUPS

Clinical Data	Control Group		Case Group		p-value
	μ	σ	μ	σ	
SBP (mmHg)	130.05	22.191	139.10	20.501	0.062
DBP (mmHg)	80.23	15.316	79.68	11.430	0.856
MAP (mmHg)	96.83	15.815	99.48	12.569	0.409
LDL (mmol/L)	2.74	1.180	3.11	1.216	0.191
HDL (mmol/L)	1.13	0.306	1.05	0.292	0.240
CHOL (mmol/L)	4.67	1.529	4.98	1.390	0.357
TRIG (mmol/L)	1.71	1.286	1.92	1.978	0.588
FBS (mmol/L)	5.91	1.772	8.05	3.599	0.002
HR (bpm)	77.77	19.753	72.58	13.370	0.191
QRS-dur (ms)	97.81	15.208	95.43	14.799	0.509
QT-int (ms)	390.32	31.233	409.85	47.258	0.051
QTc-int (ms)	424.94	31.645	433.88	32.830	0.252

No significant results that can differentiate severely blocked arteries are found in the lipid profile as well, even though HDL is one of the risk parameters used in CAD risk calculation. The finding is similar to study done by Tacoy et al. (2008) who differentiate healthy and stenosed arteries on 2760 subjects [19]. Important readings from ECG tests such as HR, QRS-dur, QT-int, and QTc-int had mean in the normal range for both groups. Their p-values are not statistically significant as well. Subject might be under hypertensions medications since they are going for ICA or CCTA procedure. A series of reading on these parameters is required using Holter monitors for example to get accurate diagnosis of the heart.

From the statistics shown in Table V, only one clinical parameter is seen to be significantly different, which is the patient's FBS (p=0.002). Case subjects tend to have higher sugar levels. The FBS data distribution is best represented in a box plot, as shown in Fig. 3. The '*' and 'o' symbols indicate outliers above the 3rd quartile level. The FRS scores are also compared. It was found that there was no significant difference in scores between the two groups. A total of 47 subjects (58.75%) had a low FRS score. This included 50% of the subjects from the Case group. Thus, the FRS score is not an accurate marker of severe arterial stenosis.

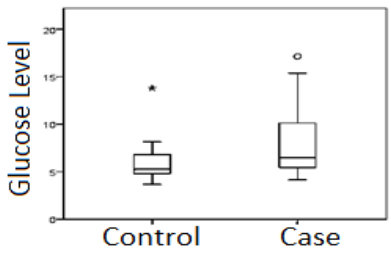

Fig. 3. Box plot of FBS from two study groups

V. CONCLUSION

The analysis of the collected data shows that there is no significant difference in the demographic and clinical information of the subjects for both study groups apart from the fasting blood sugar, in differentiating patients with severely blocked arteries. Framingham risk score results (without any adjustment) are also found irrelevant in predicting the risks of CAD, especially in detecting the severity of the stenosed coronary arteries. Thus, a pre-diagnostic alternative for the detection or prediction of coronary artery stenosis from non-invasive signal parameters of ECG or PPG is subsequently needed.

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REFERENCES

[1] A. D. Dolatabadi, S. E. Zadeh Khadem, and B. M. Asl, "Automated diagnosis of coronary artery disease (CAD) patients using optimized SVM," *Comput. Methods Programs Biomed.*, vol. 138, pp. 117–126, 2017, doi: 10.1016/j.cmpb.2016.10.011.

[2] World Health Organization, "The top 10 causes of death - Factsheet," 2020. [Online]. Available: https://www.who.int/news-room/fact-sheets/detail/the-top-10-causes-of-death.

[3] Jabatan Perangkaan Malaysia, "Department of Statistics Malaysia Press Release: Statistics on Causes of Death, Malaysia, 2021," 2021. https://www.dosm.gov.my/v1/index.php?r=column/cthemeByCat&cat=401&bul_id=R3VrRUhwSXZDN2k4SGN6akRhTStwQT09&menu_id=L0pheU43NWJwRWVSZklWdzQ4TlhUUT09 (accessed Dec. 14, 2022).

[4] J. H. Tan *et al.*, "Application of stacked convolutional and long short-term memory network for accurate identification of CAD ECG signals," *Comput. Biol. Med.*, vol. 94, 2018, doi: 10.1016/j.compbiomed.2017.12.023.

[5] M. Ahmed, "Heart Blockage – Explained With Pictures ! Heart Blockage – Mild Coronary Artery Disease Heart Blockage – Moderate Coronary Artery Disease," *MyHeart.net*, 2020. https://myheart.net/articles/heart-blockage-explained-with-pictures/ (accessed Oct. 07, 2020).

[6] N. Paradkar and S. Roy Chowdhury, "Coronary artery disease detection using photoplethysmography," in *Proceedings of the Annual International Conference of the IEEE Engineering in Medicine and Biology Society, EMBS*, 2017, pp. 100–103, doi: 10.1109/EMBC.2017.8036772.

[7] H. A. Kirişli *et al.*, "Standardized evaluation framework for evaluating coronary artery stenosis detection, stenosis quantification and lumen segmentation algorithms in computed tomography angiography," *Med. Image Anal.*, vol. 17, no. 8, pp. 859–876, 2013, doi: 10.1016/j.media.2013.05.007.

[8] A. Goyal *et al.*, "Clinical and Economic Implications of Inconclusive Noninvasive Test Results in Stable Patients with Suspected Coronary Artery Disease: Insights from the PROMISE Trial," *Circ. Cardiovasc. Imaging*, no. April, pp. 1–9, 2020, doi: 10.1161/CIRCIMAGING.119.009986.

[9] G. Phadke, M. R. Rajati, and L. Phadke, "Prediction of coronary artery disease using electrocardiography: A machine learning approach," in *Proceedings - International Conference on Machine Learning and Cybernetics*, 2020, vol. 2020-Decem, pp. 175–180, doi: 10.1109/ICMLC51923.2020.9469585.

[10] S. D. Fihn *et al.*, "2012 ACCF/AHA/ACP/AATS/PCNA/SCAI/STS guideline for the diagnosis and management of patients with stable ischemic heart diseass," *Circulation*, vol. 126, no. 25, 2012, doi: 10.1161/CIR.0b013e318277d6a0.

[11] J. Knuuti *et al.*, "2019 ESC Guidelines for the diagnosis and management of chronic coronary syndromes The Task Force for the diagnosis and management of chronic," pp. 407–477, 2020, doi: 10.1093/eurheartj/ehz425.

[12] Cleveland Clinic, "Coronary Artery Disease: SYmptoms, Causes & Treatment," 2022. https://my.clevelandclinic.org/health/diseases/16898-coronary-artery-disease.

[13] C. W. Hamm and E. Braunwald, "A classification of unstable angina revisited," *Circulation*, vol. 102, no. 1, pp. 118–122, 2000, doi: 10.1161/01.CIR.102.1.118.

[14] A. Alhosani, S. Alshizawi, S. Alali, H. Saleh, T. Assaf, and T. Stouraitis, "Automatic detection of coronary artery disease (CAD) in an ECG signal," in *ICECS 2017 - 24th IEEE International Conference on Electronics, Circuits and Systems*, 2018, vol. 2018-Janua, pp. 414–418, doi: 10.1109/ICECS.2017.8292036.

[15] W. M. S. W. Abdullah, Y. S. Yusoff, N. Basir, and M. M. Yusuf, "Mortality rates due to coronary heart disease by specific sex and age groups among Malaysians," *Lect. Notes Eng. Comput. Sci.*, vol. 2, pp. 736–741, 2017.

[16] S. D. Fihn *et al.*, "2012 ACCF/AHA/ACP/AATS/PCNA/SCAI/STS guideline for the diagnosis and management of patients with stable ischemic heart diseass," *Circulation*, vol. 126, no. 25, pp. 354–471, 2012, doi: 10.1161/CIR.0b013e318277d6a0.

[17] N. J. Bosomworth, "Practical use of the Framingham risk score in primary prevention: Canadian perspective," *Can. Fam. Physician*, vol. 57, no. 4, pp. 417–423, 2011.

[18] E. J. Benjamin *et al.*, "Heart Disease and Stroke Statistics-2019 Update: A Report From the American Heart Association," *Circulation*, vol. 139, no. 10, pp. e56–e66, 2019, doi: 10.1161/CIR.0000000000000659.

[19] G. Tacoy *et al.*, "Traditional risk factors are predictive on segmental localization of coronary artery disease," *Angiology*, vol. 59, no. 4, pp. 402–407, 2008, doi: 10.1177/0003319708318379.