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# Predictors of Nonadherence to Planned Coronary Angiography: A Retrospective Analysis

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## Abstract:

**Objective:** This study aimed to determine the predictive power of patient-related factors, socio-economic factors, condition-related factors, treatment-related factors, and health care system-related factors for nonadherence to planned coronary angiography (CAG).

**Material and Methods:** A retrospective analysis was conducted on electronic medical records (EMR) of 665 patients appointed for elective CAG at Naradhiwas Rajanagarindra Heart Center from January 2018 to December 2019. One hundred and thirty-three patients with nonadherence to planned CAG were assigned to the study group; the control group consisted of 532 patients with adherence to planned CAG.

**Results:** The retrospective data analysis revealed that divorced or widowed status (OR=3.07; 95% CI 1.54, 6.12), cerebrovascular disease comorbidity (OR=4.37; 95% CI 1.74, 10.96), prescribed diuretics (OR=2.24; 95% CI 1.26, 3.97), CAG wait time three months or longer (OR=3.34; 95% CI 1.46, 7.64) and history of parental cardiovascular disease or death from heart disease (OR=0.12; 95% CI 0.01, 0.95) were co-predictors of nonadherence to planned CAG. Socioeconomic- related factors had no predictive power for planned CAG nonadherence.

**Conclusion:** The findings of this study may contribute to the improvement of nursing service by screening groups at high risk of nonadherence and developing appropriate interventions aimed at increasing adherence to planned CAG as well the rate of positive health outcomes.

**Keywords:** nonadherence, planned coronary angiography, predictors

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## Introduction

Coronary angiography (CAG) remains the current gold standard diagnostic test available for known or suspected coronary artery disease (CAD)[1]. CAG is an invasive diagnostic procedure that comes along with its complexity, potential risks, and complications[2]. Hence, adequate equipment and a large number of personnel with special expertise in this field are required to perform this procedure[3]. In developing low- and middle-income countries like Thailand, CAG is not available in all hospitals[4]. The selection and placement of patients on waiting lists for CAG are, therefore, carefully arranged by specialist doctors. When the CAG's benefits far outweigh its known risks, an appointment is scheduled after gaining consent from patients or their families[5]. The percentage of patients going through with their scheduled CAG reported in previous studies is rather low (57.6–59%)[6,7]. In other words, the reported incidence of the refusal of scheduled CAG on the part of patients is nearly half of the total scheduled cases[6,7]. This seems to be a common problem in cardiac centers in southern Thailand[8]. The patients' refusal or inability to adhere to the planned CAG increases their risks of experiencing major adverse cardiac events (MACE) such as acute myocardial infarction (AMI), stroke, and cardiovascular mortality[9].

Non-adherence to planned CAG is not solely the patient's problem and responsibility. Adherence is a planned behavior that is affected by the interplay of five dimensions or five sets of factors. These factors are unique and involve socioeconomics, the patient, his/her clinical condition, the prescribed therapy, and the healthcare system at play, which vary according to the specific group of patients and their particular context. The terms 'adherence' or 'non-adherence' are not used for labelling or discrimination purposes[10]. Improving patient adherence to CAG would have a greater impact on cardiovascular health outcomes than simply improving a care model or applying a care innovation. Knowing the factors underpinning the decisions of patients with a planned CAG to undergo or refuse the procedure is, thus, the initial gateway strategy to empathize with, or understand, non-adherence patients as well as to raise awareness among healthcare providers. The knowledge gained from this study could be utilized to design specific interventions to overcome this problem.

Moreover, it has been shown that patients who refuse the planned CAG tend to also decline receive consecutive services from hospitals[8]. In order to maintain patient confidentiality and respect their privacy during the covid-19 pandemic, a retrospective analysis of the electronic medical records of patients scheduled for CAG was conducted. This study aimed to determine the co-predictors of non-adherence to planned CAG focusing on factors related to the patient, his/her socioeconomics, clinical condition, prescribed therapies, and health system using a predictive model to help identify patients who are more likely to not adhere to a planned CAG.

## Material and Methods

This retrospective case-control study analyzed the electronic medical records (EMRs) of patients scheduled for elective CAG over a two-year period (1 January 2018 to 31 December 2019) at Naradhiwas Rajanagarindra Heart Center in Songkhla, Thailand. The EMRs were categorized into either the 'case' or 'control' groups. The case or non-adherence group referred to patients, who failed to follow the agreed recommendations from a medical doctor regarding their planned CAG. Meanwhile, those who followed the agreed recommendations comprised the CAG adherence or the control group.

The EMRs of only patients for whom the CAG was planned for diagnostic purposes with or without a percutaneous coronary intervention (PCI), and who were at least 18 years of age and had no limitations of access to the relevant care services for their coronary disease were included. The EMRs were excluded from the 'case' group if the CAG was canceled by physicians, the patient underwent the CAG at another center, underwent emergency CAG, or died prior to the scheduled CAG date.

In order to provide power for the detection of a significant difference between the two groups, the actual sample size of the case and control groups was calculated for a case:control ratio of 1:4. Based on an 80% power and a 95% confidence interval, 665 EMRs were included in the analysis. Concerning the probability of missing data to detect a difference in proportion exposed of 0.55 and 0.40, respectively, 133 cases and 532 controls were enrolled in this study.

The data were extracted from the EMRs of eligible patients using a structured data extraction form developed and tested by the researchers. The index of item-objective congruence [IOC] of 59 sub-items of the tool and 72 items of the manual ranged from 0.6 to 1. The inter-rater reliability testing of the researcher and the two research assistants was high (0.97). Pilot testing was conducted with 67 patients (13 cases; 54 controls). The extraction of data was systematically conducted according to the guiding manual and procedures over a 3-month period, from August to October 2021.

Ethical approval was obtained from the Human Research Ethics Committee (HREC), Faculty of Medicine, Prince of Songkla University (REC. 64-172-19-9). Since gaining first-hand consent from the participants was not possible, the requirement for consent was waived with respect to the protection of human subjects. Only the permitted data as set out were extracted and retrieved. The data remained anonymous, and no patient or third-party identification was used with coding for all the documentation and records. Finally, all data were kept in locked secure places and a personal computer.

Concerning the data analysis, since the variables selected in this study were independent variables, listwise deletion was used to manage the missing values[11]. The Mann-Whitney U test, Pearson Chi-square test, likelihood ratio, and Fisher's exact test were used to explore the differences between the two groups. The bivariate analysis was used to analyze the potential predictive factor variables and to select the ensuing important predictors for the logistic regression model. The relationship between multiple variables and the probability of finding non-adherence to a planned CAG were determined using a logistic regression model. A goodness-of-fit test for the regression model was performed using the likelihood ratio test and the Hosmer-Lemeshow test. The discrimination power of the regression model was assessed using the area under the receiver operating characteristic (ROC) curve.

## Results

Our sample consisted of 665 EMRs, which included 532 and 133 adherence and non-adherence cases to a planned CAG, respectively. Significant differences were found between the two groups in terms of age; marital status; level of education; income; initial medical diagnosis; glomerular filtration rate (GFR); cerebrovascular disease (CVD) comorbidity; parental history of CAD or death due to CAD; current use of beta-blockers, antilipidemic drugs, diuretics, and nitrates; and CAG wait time (Table 1).

Table 2 presents the bivariate analysis results of the relationship between the independent variables and the presence of non-adherence to a planned CAG. Increased risk for non-adherence to a planned CAG was significantly associated with an age of 65 years and older (OR=1.72, 95% CI 1.17, 2.54, p-value=0.006), widowed/divorced vs. married (OR=2.67, 95% CI 1.61, 4.49, p-value <0.001), diagnosis of NSTEMI (OR=2.92, 95% CI 1.58, 5.40, p-value<0.001), cardiomyopathy (OR=2.64, 95% CI 1.25, 5.55, p-value=0.011) or heart failure (OR=4.63, 95% CI 1.37, 15.64, p-value=0.014) vs. atherosclerotic heart disease, GFR less than 90 mL/min (OR=2.09, 95% CI 1.01, 4.32, p-value=0.045), CVD comorbidity (OR=2.21, 95% CI 1.09, 4.45, p-value=0.026), current use of diuretics (OR =1.59, 95% CI 1.05, 2.40, p-value=0.026), and a CAG waiting time three months or longer (OR=3.53, 95% CI 2.01, 6.24, p-value<0.001) (Table 2).

**Table 1** Baseline characteristics of the study population. Values represent n (%). Comparisons were performed using the Mann–Whitney test for continuous variables and the Pearson Chi-square, Likelihood Ratio, and Fisher's exact tests for categorical variables

| Variables | Cases (n=133) | Controls (n=532) | p-value |
|---|---|---|---|
| **Patient-related factors** | | | |
| Age (years) | Mdn (IQR)=68 (20) | Mdn (IQR)=63 (16) | 0.002 |
| Sex | | | 0.67 |
| Male | 92 (69.2) | 378 (71.1) | |
| Female | 41 (30.8) | 154 (28.9) | |
| Marital status | | | 0.001 |
| Single | 7 (5.3) | 22 (4.1) | |
| Married | 98 (73.7) | 461 (86.7) | |
| Widowed/divorced | 28 (21.1) | 49 (9.2) | |
| **Social and economic factors** | | | |
| Education | n=48 | n=425 | 0.016 |
| Uneducated | 7 (14.6) | 13 (3.1) | |
| Primary school | 23 (47.6) | 202 (47.5) | |
| Secondary school | 7 (14.6) | 78 (18.4) | |
| Higher education | 11 (22.9) | 132 (31.1) | |
| Occupation | | | 0.015 |
| Unemployed | 56 (42.1) | 199 (37.4) | |
| Government employee | 23 (17.3) | 155 (29.1) | |
| Private-sector employee/farmer | 19 (14.3) | 83 (15.6) | |
| Freelance work | 35 (26.3) | 95 (17.9) | |
| Income* | n=51 | n=395 | 0.028 |
| No income | 32 (62.7) | 169 (42.8) | |
| Low income | 15 (29.4) | 151 (38.2) | |
| Moderate income | 2 (3.9) | 52 (13.2) | |
| High income | 2 (3.9) | 23 (5.8) | |
| Insurance | | | 0.606 |
| Universal health coverage | 43 (32.2) | 146 (27.3) | |
| Social security scheme | 11 (8.3) | 38 (7.1) | |
| Government employee scheme | 75 (56.4) | 326 (61.3) | |
| Other insurance | 4 (3.0) | 22 (4.1) | |
| Province of residence | | | 0.248 |
| Narathiwat | 23 (17.3) | 75 (14.1) | |
| Yala | 3 (2.3) | 27 (5.1) | |
| Pattani | 24 (18.0) | 77 (14.5) | |
| Songkhla | 44 (33.1) | 168 (31.6) | |
| Phatthalung | 6 (4.5) | 49 (9.2) | |
| Satun | 23 (17.3) | 77 (14.5) | |
| Trang | 2 (1.5) | 12 (2.3) | |
| Other province | 8 (6.0) | 47 (7.1) | |
| **Condition-related factors** | | | |
| Initial medical diagnosis | | | 0.01 |
| STEMI | 10 (7.5) | 48 (9.0) | |
| NSTEMI | 56 (42.1) | 160 (30.1) | |
| Unstable angina | 16 (12.0) | 67 (12.6) | |
| Stable angina | 12 (9.0) | 63 (11.8) | |
| Atherosclerotic heart disease | 15 (11.3) | 125 (23.5) | |
| Cardiomyopathy | 19 (14.3) | 60 (11.3) | |
| Heart failure | 5 (3.8) | 9 (1.7) | |

**Table 1** (continued)

| Variables | Cases (n=133) | Controls (n=532) | p-value |
|---|---|---|---|
| NYHA | n=95 | n=488 | 0.731 |
| Class I | 28 (29.5) | 136 (27.9) | |
| Class II | 38 (40) | 210 (43) | |
| Class III | 17 (17.9) | 97 (19.9) | |
| Class IV | 12 (12.6) | 45 (9.2) | |
| LVEF (%) | n=66 | n=314 | |
| | Mdn (IQR)=48.5 (34) | Mdn (IQR)=52.5 (32) | 0.052 |
| GFR (mL/min) | n=78 | n=531 | |
| | Mdn (IQR)=50.5 (41) | Mdn (IQR)=71 (33) | <0.001 |
| Cholesterol (mg/dL) | n=61 | n=359 | |
| | Mdn (IQR)=169 (68) | Mdn (IQR)=160 (59) | 0.616 |
| CVD | n=131 | n=527 | |
| | 13 (10.0) | 25 (4.7) | 0.023 |
| Smoking behavior | n=100 | n=513 | 0.119 |
| Never smoked | 40 (40.0) | 215 (41.9) | |
| Former smoker | 37 (37.0) | 223 (43.5) | |
| Current smoker | 23 (23.0) | 75 (14.6) | |
| Previous MI | 17 (12.8) | 83 (15.6) | 0.416 |
| Parental history of CAD or death due to CAD | n=63 | n=480 | |
| | 1 (1.6) | 61 (12.7) | 0.009 |
| **Therapy-related factors** | | | |
| Cardiovascular medications | n=124 | n=531 | |
| Beta-blockers | 73 (58.9) | 370 (69.7) | 0.021 |
| Antilipidemic drugs | 100 (80.6) | 466 (87.8) | 0.037 |
| Diuretics | 47 (37.9) | 147 (27.7) | 0.025 |
| Nitrates | 48 (38.7) | 258 (48.6) | 0.047 |
| Total number of medications | n = 124 | n=531 | 0.080 |
| <5 | 20 (16.1) | 56 (10.5) | |
| ≥5 | 104 (83.9) | 475 (89.5) | |
| Adherence to medications[1] | n=124 | n=531 | |
| | 108 (87.1) | 443 (83.4) | 0.314 |
| Adherence to follow-up[2] | n=34 | n=214 | |
| | 28 (82.4) | 194 (90.7) | 0.142 |
| Previous CAG without PCI | 9 (6.8) | 48 (9.0) | 0.406 |
| Previous CAG with PCI | 13 (9.8) | 76 (14.3) | 0.172 |
| Previous CABG | 1 (0.8) | 9 (1.7) | 0.696 |
| **Health system-related factors** | | | |
| Waiting time for CAG (days) | Mdn (IQR)=125 (28.5) | Mdn (IQR)=118 (52.7) | <0.001 |

*Defined as monthly income based on the 2020 criteria of the Thai National Housing Authority (low income <28,900 baht, moderate income 28,901-46,500 baht, high income >46,500 baht)

STEMI=ST-segment elevation myocardial infarction, NSTEMI=non-ST-segment elevation myocardial infarction, NYHA=New York Heart Association, LVEF=left ventricular ejection fraction, GFR=glomerular filtration rate, CVD=cerebrovascular disease, MI=myocardial infarction, CAD=coronary artery disease, CAG=coronary angiography, PCI=percutaneous coronary intervention; CABG=coronary artery bypass graft surgery

100% of prescribed doses taken over a given time period[1]

100% of timely follow-up visits as appointed over a given time period[2]

**Table 2** Bivariate analysis results of the relationship between the independent variables and the presence of non-adherence to planned CAG.

| Variables | OR | 95% CI | | p-value |
|---|---|---|---|---|
| | | LL | UL | |
| **Patient-related factors** | | | | |
| Age (years) | | | | |
| <65 | Ref. | | | |
| ≥65 | 1.72 | 1.17 | 2.54 | 0.006 |
| Sex | | | | |
| Male | Ref. | | | |
| Female | 1.09 | 0.72 | 1.65 | 0.670 |
| Marital status | | | | |
| Married | Ref. | | | |
| Single | 1.49 | 0.61 | 3.61 | 0.368 |
| Widowed/divorced | 2.68 | 1.61 | 4.49 | <0.001 |
| **Social and economic factors** | | | | |
| Education (n=473) | | | | |
| Uneducated | Ref. | | | |
| Primary school | 0.21 | 0.07 | 0.58 | 0.003 |
| Secondary school | 0.16 | 0.05 | 0.55 | 0.003 |
| Higher education | 0.15 | 0.05 | 0.46 | 0.001 |
| Occupation | | | | |
| Unemployed | Ref. | | | |
| Government employee | 0.52 | 0.31 | 0.89 | 0.018 |
| Private-sector employee/farmer | 0.81 | 0.45 | 1.45 | 0.485 |
| Freelance work | 1.31 | 0.81 | 2.13 | 0.279 |
| Income (n=446) | | | | |
| No income | Ref. | | | |
| Low income | 0.52 | 0.27 | 1.01 | 0.052 |
| Moderate income | 0.21 | 0.04 | 0.87 | 0.033 |
| High income | 0.45 | 0.11 | 2.04 | 0.307 |
| Insurance | | | | |
| Universal health coverage | Ref. | | | |
| Social security scheme | 0.98 | 0.46 | 2.08 | 0.964 |
| Government employee scheme | 0.78 | 0.51 | 1.19 | 0.252 |
| Other insurance | 0.61 | 0.21 | 1.88 | 0.398 |
| Province of residence | | | | |
| Songkhla | Ref. | | | |
| Narathiwat | 1.17 | 0.66 | 2.07 | 0.589 |
| Yala | 0.42 | 0.12 | 1.46 | 0.175 |
| Pattani | 1.19 | 0.67 | 2.09 | 0.547 |
| Phatthalung | 0.46 | 0.18 | 1.16 | 0.102 |
| Satun | 1.14 | 0.64 | 2.02 | 0.652 |
| Trang | 0.63 | 0.13 | 2.94 | 0.563 |
| Other province | 0.65 | 0.28 | 1.47 | 0.303 |
| **Condition-related factors** | | | | |
| Initial medical diagnosis | | | | |
| Atherosclerotic heart disease | Ref. | | | |
| STEMI | 1.74 | 0.73 | 4.13 | 0.212 |
| NSTEMI | 2.92 | 1.58 | 5.40 | <0.001 |
| Unstable angina | 1.99 | 0.93 | 4.27 | 0.078 |
| Stable angina | 1.59 | 0.70 | 3.59 | 0.268 |
| Cardiomyopathy | 2.64 | 1.25 | 5.55 | 0.011 |
| Heart failure | 4.63 | 1.37 | 15.64 | 0.014 |

**Table 2** (continued)

| Variables | OR | 95% CI | | p-value |
|---|---|---|---|---|
| | | LL | UL | |
| NYHA (n=583) | | | | |
| Class I | Ref. | | | |
| Class II | 0.87 | 0.51 | 1.49 | 0.635 |
| Class III | 0.85 | 0.44 | 1.64 | 0.631 |
| Class IV | 1.29 | 0.61 | 2.75 | 0.502 |
| LVEF (%) (n=380) | | | | |
| ≥55 | Ref. | | | |
| <55 | 1.37 | 0.79 | 2.35 | 0.252 |
| GFR (mL/min) (n=609) | | | | |
| ≥90 | Ref. | | | |
| <90 | 2.09 | 1.01 | 4.32 | 0.045 |
| Cholesterol (mg/dL) (n=420) | | | | |
| ≤200 | Ref. | | | |
| >200 | 1.28 | 0.68 | 2.38 | 0.436 |
| CVD (n=658) | | | | |
| No | Ref. | | | |
| Yes | 2.21 | 1.09 | 4.45 | 0.026 |
| Smoking behavior (n=613) | | | | |
| Never smoked | Ref. | | | |
| Former smoker | 0.89 | 0.54 | 1.44 | 0.643 |
| Current smoker | 1.64 | 0.92 | 2.93 | 0.089 |
| Previous MI | | | | |
| No | Ref. | | | |
| Yes | 0.79 | 0.45 | 1.38 | 0.417 |
| Parental history of CAD or death due to CAD (n=543) | | | | |
| No | Ref. | | | |
| Yes | 0.11 | 0.01 | 0.81 | 0.031 |
| **Therapy-related factors** | | | | |
| Cardiovascular medications (n=655) | | | | |
| Aspirin | | | | |
| No | Ref. | | | |
| Yes | 0.54 | 0.28 | 1.02 | 0.060 |
| ARBs | | | | |
| No | Ref. | | | |
| Yes | 0.56 | 0.31 | 1.01 | 0.054 |
| Beta blockers | | | | |
| No | Ref. | | | |
| Yes | 0.62 | 0.41 | 0.93 | 0.021 |
| Antilipidemic drugs | | | | |
| No | Ref. | | | |
| Yes | 0.58 | 0.34 | 0.97 | 0.039 |
| Diuretics | | | | |
| No | Ref. | | | |
| Yes | 1.59 | 1.05 | 2.40 | 0.026 |
| Nitrates | | | | |
| No | Ref. | | | |
| Yes | 0.66 | 0.44 | 0.99 | 0.048 |
| Total number of medications (n=655) | | | | |
| ≥5 | Ref. | | | |
| <5 | 1.63 | 0.93 | 2.83 | 0.083 |
| Adherence to follow-up (n=248) | | | | |
| No | Ref. | | | |
| Yes | 0.48 | 0.17 | 1.31 | 0.149 |

**Table 2** (continued)

| Variables | OR | 95% CI | | p-value |
|---|---|---|---|---|
| | | LL | UL | |
| Adherence to medications (n=655) | | | | |
| No | Ref. | | | |
| Yes | 1.34 | 0.75 | 2.37 | 0.315 |
| Previous CAG without PCI | | | | |
| No | Ref. | | | |
| Yes | 0.73 | 0.35 | 1.53 | 0.408 |
| Previous CAG with PCI | | | | |
| No | Ref. | | | |
| Yes | 0.65 | 0.34 | 1.21 | 0.174 |
| Previous CABG | | | | |
| No | Ref. | | | |
| Yes | 0.44 | 0.05 | 3.51 | 0.438 |
| **Health system-related factors** | | | | |
| Waiting time for CAG (months) | | | | |
| <3 | Ref. | | | |
| ≥3 | 3.53 | 2.01 | 6.24 | <0.001 |

OR=odds ratio, CI=confidence inverval, LL=lower limit, UL=upper limit, STEMI=ST-segment elevation myocardial infarction, NSTEMI=non-ST-segment elevation myocardial infarction, NYHA=New York Heart Association, LVEF=left ventricular ejection fraction, GFR=glomerular filtration rate, CVD=cerebrovascular disease, CAD=coronary artery disease, MI=myocardial infarction, ARBs=angiotensin receptor blockers, CAG=coronary angiography, PCI=percutaneous coronary intervention, CABG=coronary artery bypass graft surgery

The primary (OR=0.21, 95% CI 0.07, 0.58, p-value=0.003), secondary (OR=0.16, 95% CI 0.05, 0.55, p-value =0.003), and higher (OR=0.15, 95% CI 0.05, 0.46, p-value =0.001) education levels; government employee vs. unemployed (OR=0.52, 95% CI 0.31, 0.89, p-value=0.018); a moderate-level income vs. no income (OR=0.21, 95% CI 0.04, 0.87, p-value=0.033); parental history of CAD or death due to CAD (OR=0.11, 95% CI 0.01, 0.81, p-value =0.031); current use of beta-blockers (OR=0.62, 95% CI 0.41, 0.93, p-value=0.021), antilipidemic drugs (OR=0.58, 95% CI 0.34, 0.97, p-value=0.039), and nitrates (OR= 0.66, 95% CI 0.44, 0.99, p-value=0.048) were significantly associated with a decreased risk of non-adherence to a planned CAG (Table 2).

In the multivariable logistic regression analysis, widowed/divorced vs. married (OR=3.07, 95% CI 1.54, 6.12, p-value=0.001), CVD comorbidity (OR=4.37, 95% CI 1.74, 10.96, p-value=0.002), current use of diuretics (OR=2.24, 95% CI 1.26, 3.97, p-value=0.006), and a CAG wait time 3 months or longer were strongly associated with non-adherence to a planned CAG (OR=3.34, 95% CI 1.46, 7.64, p-value=0.004) (Table 3). By contrast, parental history of CAD or death due to CAD was inversely associated with non-adherence (OR=0.12, 95% CI 0.01, 0.95, p-value=0.045) (Table 3).

Table 4 displays the results of the goodness-of-fit testing of the logistic regression model. The likelihood ratio test confirmed the model to be fitted with all of its five predictors ($\chi^2$=47.11, p-value<0.000). Meanwhile, the Hosmer-Lemeshow test confirmed that there was no evidence of a lack of fit ($\chi^2$=4.84, p-value=0.564). The discrimination power of the model was estimated using the area under the ROC curve; it yielded a value of 0.73 (Figure 1).

**Table 3** Multivariate analysis results using multiple logistic regression (N=537)

| Predictors | β | SE | Wald | p-value | Adjusted OR | 95% CI | |
|---|---|---|---|---|---|---|---|
| | | | | | | LL | UL |
| CVD | | | | | | | |
| (Ref. No) | | | | | | | |
| Yes | 1.47 | 0.46 | 9.93 | 0.002 | 4.37 | 1.74 | 10.96 |
| Waiting time for CAG | | | | | | | |
| (Ref.<3 months) | | | | | | | |
| ≥3 months | 1.21 | 0.42 | 8.16 | 0.004 | 3.34 | 1.46 | 7.64 |
| Marital status | | | | | | | |
| (Ref. married) | | | | | | | |
| Widowed/divorced | 1.12 | 0.35 | 10.19 | 0.001 | 3.07 | 1.54 | 6.12 |
| Single | −0.11 | 0.77 | 0.02 | 0.879 | 0.88 | 0.19 | 4.03 |
| Diuretics | | | | | | | |
| (Ref. No) | | | | | | | |
| Yes | 0.81 | 0.29 | 7.64 | 0.006 | 2.24 | 1.26 | 3.97 |
| Parental history of CAD or death due to CAD | | | | | | | |
| (Ref. No) | | | | | | | |
| Yes | −2.07 | 1.03 | 4.03 | 0.045 | 0.12 | 0.01 | 0.95 |
| Constant | −3.51 | 0.42 | 68.88 | 0.000 | 0.03 | | |

SE=standard error, OR=odds ratio, CI=confidence inverval, LL=lower limit, UL=upper limit, CVD=cerebrovascular disease, CAD=coronary artery disease, CAG=coronary angiography

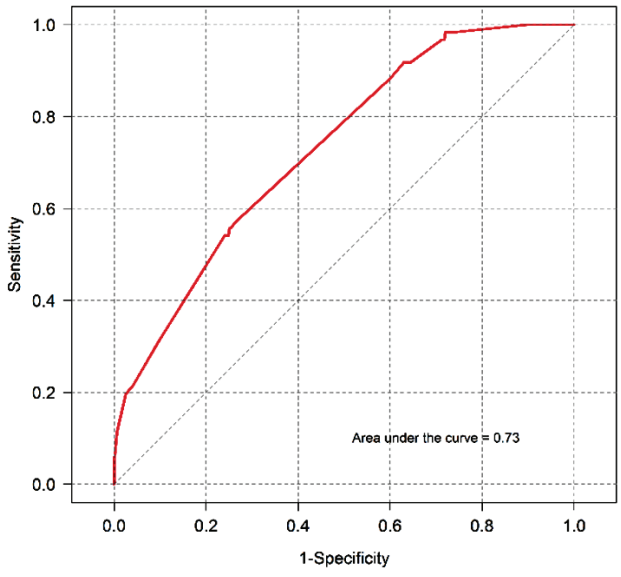


**Figure 1** ROC curve of the discriminatory power of the model

**Table 4** The goodness-of-fit of the logistic regression model

| Goodness of fit | $\chi^2$ | df | p-value |
|---|---|---|---|
| Likelihood ratio test | 47.11 | 6 | <0.001 |
| Hosmer-Lemeshow test | 4.84 | 6 | 0.564 |

df=degree of freedom

The topmost three reasons for not undergoing the CAG as scheduled given by the participants were having an optimistic symptom perception (45.1%), fear and uncertainty concerning the safety and efficacy of the procedure (26.3%), and not being ready or available to undergo the procedure and cope with its potential severe comorbidities (9.1%).

## Discussion

The evidence generated from this study on the five co-variables, which simultaneously predict the probability that patients will not adhere to a planned CAG, supports the WHO conceptual model of adherence well[10]. However, no contribution of social- and economic-related factors on non-adherence to a planned CAG was observed in the present study. Our findings differ from those of an Indonesian study, which identified resource constrains, such as poor transportation, socio-economic status, and insurance type, as factors contributing to non-adherence and unequal access to CAG[6]. A possible explanation for this might be the effectiveness of the Thai Universal Health Coverage Scheme in this regard, which covers the whole cost of CAG for the low-income Thai patients[12]. Along with this, the 'One-Tambon-One-Ambulance' ('tambon' in Thai means 'subdistrict' in English) policy provides free patient transport to and from the hospital[12]. Hence, these might play a role as an extraneous variable, which decreases the impact of this socioeconomic dimension.

As aforementioned, the co-predictors of non-adherence to a planned CAG identified in this study are mostly consistent with the results obtained by previous adherence/non-adherence studies. These predictors include being widowed/divorced, having CVD comorbidity, currently using diuretics, and having a CAG waiting time of three months or longer. However, most studies have focused on medication adherence[13-15,20-22], while WHO has suggested studying all therapeutic behaviors related to adherence, beyond the prescribed pharmacological therapy, in order to have a holistic health approach to such topics[10].

It is somewhat surprising that the current use of diuretics was found to be a co-variable that increased the likelihood to non-adherence to a planned CAG. This result has not been previously reported. An earlier study mentioned the relationship between the current use of medications and symptom relief and refusal to undergo CAG. It seems possible to argue in the same fashion since diuretics were suggested in the 2022 AHA/ACC/HFSA Guideline for the Management of Heart Failure[16]. This argument is further supported by the finding that the majority of non-adherents were receiving diuretics and that this fact was reported as the most common reason for not undergoing CAG as planned.

The accuracy of the prediction of non-adherence to a planned CAG by the model based on the selected five variables was not able to reach the same level of excellence like the previous model studies focusing on medication adherence[13,17-22]. This is likely to be related to potential limitations and constraints encountered by the model employed in this novel study. The present study did not control for potential and unknown confounding factors or for confounding between predictors. The significant differences in some baseline variables of the case and control groups might have influenced the true association and the direction of their effects beyond the exposure to such factors[23].

Another issue is the fact that model accuracy may be improved by equal representation achieved via matching controls to cases. Matching was not employed in this study. Since this study was a retrospective analysis of secondary data, the phenomenon of missing data was not beyond expectation. Hence, some relevant and essential information was inevitably unavailable for analysis. Nevertheless, the researcher employed the listwise deletion method to manage the missing data. Thus, the cases with missing variables of interest were deleted, resulting in a reduced sample and the loss of some statistical power[11]. Finally, since this study is novel, and the interesting variables were selected based on the previous adherence studies not directly focused on this outcome, not all potentially important variables may have been considered.

## Conclusion

This study developed a logistic regression model to assess/ascertain the relationships between a set of predictors and a response variable. Four variables—

widowed/divorced, CVD comorbidity, current use of diuretics, and a CAG wait time of 3 months or longer—were found more commonly among cases and associated with the probability of non-adherence to a planned CAG. By contrast, parental history of CAD or death due to CAD was inversely associated with non-adherence. The quality of the devised model may be somewhat limited by the retrospective nature of the study.

Regardless of the high predictive power of the model, the five predictive variables provide a sense of reality in this care context. Indeed, CAG non-adherence is simultaneously affected by several factors and not solely by patient responsibility. However, some questions and concerns remain unanswered due to the limitations of this retrospective EMR review study. Particularly, the term 'non-adherence' was used in this study without any knowledge as to whether or not all patients actively agreed with the CAG recommendation of the attending physician and the relevant scheduling. To this end, the reasons for or factors that lead to non-adherence to a planned CAG should not be overlooked and/or oversimplified. Instead of blaming or labelling patients, healthcare providers should beware their role as significant actors as well as factors in providing particular support to patients and their relatives, which could lead to an increase in CAG adherence and ultimately to a better quality of life for the patients and their loved ones and even to saving patients' lives.

Multicenter studies are required to improve the generalization and contribution of this study. Further studies that aim to examine the same outcome using the questionnaire-based investigative approach are also suggested in order to strengthen the power of the study outcome prior to utilizing the study findings to guide clinical practice.

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## Conflict of interest

We declare no conflicts of interest.

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