ORIGINAL ARTICLE

Appropriate Use of Coronary Angiogram among Service Patients at the UP-Philippine General Hospital in the Year 2019

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ABSTRACT

Rationale. Coronary artery disease (CAD) is the leading cause of death worldwide and coronary angiography (CA) remains the gold standard for its diagnosis. However, proper patient selection for CA is important to avoid unnecessary risks and expense. The American College of Cardiology (ACC), with other major organizations, developed Appropriate Use Criteria (AUC) for CA. AUC assist clinicians in decision making on whether to use the tests according to indications and objectively assess if these tests are appropriately utilized. This is the first study to determine the appropriateness of CA performed and the clinical and angiographic profile among adult service patients in UP-PGH.

Objectives. To determine (1) the indications for CA and its appropriateness based on 2012 AUC for Diagnostic Catheterization by the ACC, (2) the clinical profile of patients who underwent CA among adult service patients at UP-PGH and (3) the angiographic profile of these patients.

Methods. This cross-sectional study included all CA studies performed on adult service patients from January to December 2019. Demographic and clinical profiles, non-invasive tests, and angiographic findings were collected. The primary outcome determined was the appropriateness of the indications for each CA performed based on AUC scores. Descriptive analysis using frequencies and mean values with standard deviations were used.

Results. Among the 515 patients included, majority were males, above 50 years of age, with normal eGFR, presented initially with chest pain, and with a presenting diagnosis of chronic coronary syndrome. Majority of these patients had obstructive CAD (75%), with left anterior descending artery as the most frequently involved vessel. Non-obstructive CAD was found in 11% while normal coronaries were noted in 14% of these patients. Our findings showed that 99.8% of the CA performed were appropriate, of which majority (54%) had an AUC score of A9. STEMI or a suspicion of STEMI, with an A9 score, was the most frequently encountered indication at 33% of the time.

Conclusion. Majority (99%) of the CA studies performed in the PGH cardiac catheterization laboratory for the year 2019 were executed based on highly appropriate indications (AUC scores A7 to A9) and followed Class I and II recommendations from guidelines. The allocation of resources is deemed to be well-utilized based on the data generated from this study.

Key Words: appropriate use criteria, coronary angiography, cardiac catheterization

INTRODUCTION

Coronary artery disease (CAD), which remains a major health problem worldwide, is part of the spectrum of ischemic heart disease (IHD). According to the World Health Organization (WHO), IHD, together with other cardiovascular diseases, has been the leading cause of death globally, accounting for 31% of all deaths in 2015.[1] Locally, cardiovascular diseases is also the leading cause of death

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with 22.3% of total deaths in 2013.[2] Because of the high risk of death associated with CAD, methods to increase early recognition and diagnosis are important to render appropriate management to improve outcome and prevent death.

Diagnostic approach and management vary depending on the clinical presentation of patients. For patients with stable IHD, management is primarily conservative with medical treatment with beta blockers, anti-platelet therapy, angiotensin converting enzyme inhibitors or angiotensin receptor blockers, and statins.[3] However for patients who remain symptomatic despite maximal medical therapy and for patients with high-risk criteria based on noninvasive testing, diagnostic Coronary angiography (CA), and possible revascularization, is recommended.[3] Among patients with Non-ST elevation acute coronary syndrome (NSTEACS), early invasive strategy with CA and revascularization is recommended for those who have recurrent symptoms or ischemia despite adequate medical therapy or for those who are at high risk, as categorized by clinical findings (heart failure, serious ventricular arrhythmias) and noninvasive test findings (significant LV dysfunction with low EF).[4] For patients with ST elevation myocardial infarction (STEMI), CA with revascularization is recommended.[5]

Coronary angiography has been widely used to evaluate patients with known or suspected CAD.[6] It remains to be the gold standard for diagnosing CAD. Results of the angiogram provide vital information that help clinicians decide on the direction of management – whether to recommend revascularization via percutaneous transluminal coronary angioplasty (PTCA), coronary artery bypass grafting (CABG), or optimal medical management.[6,7] Likewise, these results provide significant information to determine prognosis.[6,7] However, CA exposes the patients to radiation, infrequent risks such as arrhythmias, stroke and myocardial infarction as well as cost.[8] Proper selection of patients for CA has been given attention to avoid the risks, adverse effects and costs.

The American College of Cardiology (ACC), in collaboration with other societies, developed the Appropriate Use Criteria (AUC) for Diagnostic Catheterization in 2012 with the aim of ensuring rational use of cardiovascular services and assisting physician with decision making to provide high quality service (Appendix A).[6] General indications for CA in the assessment of CAD include clinical suspicion for acute coronary syndromes (ACS), evaluation of suspected or known obstructive CAD, use of adjunctive invasive diagnostic technologies, investigation of arrhythmias; preoperative evaluation and risk stratification were discussed and stated. Conditions other than CAD such as valvular heart disease, cardiomyopathies and pulmonary hypertension were also evaluated using CA. Based on the guideline, indication criteria for CA are categorized into three based on appropriateness of use: Appropriate, Uncertain and Inappropriate. If classified as "Appropriate" for a specific indication, the performance of CA is generally acceptable and is a reasonable approach for the indication. If classified as "Uncertain", performing the CA may be generally acceptable and may be a reasonable approach for the specific indication. Uncertainty also implies that more research and/or patient information is needed to more definitively classify the test based on indication. If classified as "Inappropriate", performing CA is not generally acceptable and is not a reasonable approach for the indication.[6] AUC assist clinicians in decision making whether to use the tests or not according to indications and objectively assess if tests are appropriately utilized.

In a local retrospective case series at a private tertiary hospital in Manila, among 297 patients who underwent CA over a span of 5 years, 72% had obstructive CAD, 13% had non-obstructive CAD while 15% had normal findings and most procedures were deemed appropriate (86.9%).[9] As of this writing, there are no local published data in the setting of a government tertiary hospital on the appropriateness and profile of patients who underwent CA.

Implication and Importance

At present, around 600 to 700 service patients per year undergo CA at the University of the Philippines – Philippine General Hospital (UP-PGH). The cost of each CA is approximately Php25,000.00. As the hospital shoulders the cost of this test for service patients, it therefore utilizes a large portion of the hospital funds. Based on our review of the research compendium of the UP-PGH Division of Cardiovascular Medicine and the research registry of the UP-PGH Department of Medicine, there have been no previous studies looking into the appropriateness of use of CA among adult service patients in UP-PGH. This study will provide baseline data on the appropriate use of CA and the clinical and angiographic profiles of patients who undergo this test. These data may be useful to improve diagnostic decision making for patients and intensify health programs that will help identify patients with coronary artery disease. The results of this study can also lead to identification of factors that may be addressed to improve appropriate test utilization, and to reduce costs and delays in decision-making for CA, thus improving the delivery of our health services. Likewise, the results of this research can also initiate creation of local guidelines in recommending CA in the Philippines.

OBJECTIVES

General Objective

To determine the appropriate use of coronary angiogram based on the 2012 Appropriateness Use Criteria for Diagnostic Catheterization by the American College of Cardiology among adult service patients who underwent coronary angiography at the Philippine General Hospital from January 1, 2019, to December 31, 2019, and describe their clinical and angiographic profile.

Primary Objective

To determine the indications for coronary angiogram among adult service patients and its appropriateness using the 2012 Appropriateness Use Criteria for Diagnostic Catheterization by the American College of Cardiology.

Secondary Objectives

1. To describe the clinical profile of adult service patients who underwent coronary angiogram at the Philippine General Hospital, in terms of:
   a. Baseline characteristics and demographics
   b. Chief complaint
   c. Estimated Glomerular Filtration Rate (eGFR)

2. To describe the angiographic profile of these patients in terms of:
   a. Significant lesions present
   b. Coronary artery/arteries involved

METHODS

Study Design

Cross-sectional design

Study Setting and Duration

This study was done at the University of the Philippines – Philippine General Hospital (UP-PGH), Department of Medicine, and Cardiac Catheterization Laboratory. Data of adult service patients who have undergone CA between January 2019 to December 2019 were collected.

Sampling, Study Population, and Data Collection

All adult service patients (older than 18 years old) who have undergone CA from January 2019 to December 2019 were screened using the CA database and angiogram reports. All 515 patients who underwent CA in this 12-month period were included in this review. The indications for the angiogram, clinical profiles and angiographic findings were determined from the database and angiogram reports. Review of medical records were done in instances when the needed data were not available in the database and angiogram reports. We were able to retrieve all necessary data, except for 2 echocardiogram reports, using the database and the medical records. No patients were excluded in the analysis.

Operational definitions of terms used in the study are in Appendix B. Demographics were recorded in the data collection sheet (Appendix C). Pertinent symptoms, clinical diagnosis, risk factors, laboratory results and echocardiographic findings were also recorded. The official results of patients' angiogram were reviewed in the cardiac catheterization laboratory's files.

The indications were categorized based on the 2012 AUC guidelines and were as follows: 1. Known or suspected acute coronary syndrome, 2. Suspected CAD without non-invasive test, 3. Suspected CAD with prior non-invasive test, 4. Known obstructive CAD (prior MI, prior CABG), 5. Arrhythmias, 6. Preoperative coronary evaluation for non-cardiac surgery in stable patients, 7. Evaluation of valvular disease, 8. Cardiomyopathies, 9. Congenital heart disease, and 10. Heart failure. The appropriateness of each indication was then classified as Appropriate, Uncertain or Inappropriate accordingly. Disagreement on classification between two authors were settled via a consensus reached after discussion with another author. We classified the indications for CA based on their AUC score as well as their Class of Recommendation.

Information abstracted from the data collection forms were encoded into an electronic database. All information from specific patients were anonymized, de-identified and kept strictly confidential.

Outcomes

The primary outcome investigated was the indication and appropriateness based on 2012 Appropriateness Use Criteria for Diagnostic Catheterization by the American College of Cardiology. The clinical and angiographic profiles of the patients were determined as secondary outcomes.

Data Analysis

Descriptive analysis was used to summarize the data collected. Mean values with standard deviation were reported for quantitative variables, while proportions and frequencies were reported for qualitative variables.

Ethical Issues

The protocol was submitted to the University of the Philippines Manila Research Ethics Board (UPMREB) for ethics review and approval. The study was conducted after approval was granted by the UPMREB. The study complied with the Data Privacy Act of 2012. A waiver of informed consent was requested based on the National Ethical Guidelines for Health and Health-Related Research (NEGHHR) 2017: 5.1.1 The research presents no more than minimal risk; 5.2 Medical Records as example of minimal risk (NEGHHR 2017 page 102) Review of medical records, if anonymity can be maintained and if information sought is considered non-sensitive (Data Privacy Act of 2012). This meant that because the data set was successfully anonymized – and therefore, no longer permits identification of the individual to whom the data set pertained – it was taken out of the scope of the Data Privacy Act (102).

To ensure confidentiality, the identities of patients were assigned a number code and no other information were obtained aside from what was stated in the protocol. The investigators ensured that hospital policies on handling medical records were observed. The collected data were stored in the Clinical Research Unit locked cabinets for 2 years and were accessible only to the investigators and research assistant. The research assistant hired was not an employee of PGH. They were trained on how to conduct

data collection and oriented on the policies to be followed. In case of queries, the primary investigator gave the final decision. Anonymity of participants including the patients and physicians will be assured during publication. There were no direct benefits and risks to the patients and physicians. There was no conflict of interest in this study from financial, familial, or proprietary considerations of the principal investigator, co-investigators or the study site.

RESULTS

Demographic and Clinical Profile

A total of five hundred and fifteen (515) patients who underwent CA were included in this study. Majority of the patients were male (74%). Most of the patients were above the age of 50 years old (76%) with a mean age of 57.47± 9.91 (SD) years at the time of the procedure. Among those included, 38% were admitted as emergency cases, while the majority (62%) of the admissions were elective. The most common reason for hospitalization is angina in 81% of patients, followed by dyspnea or exertional dyspnea (14%).

Among the patients studied, majority had an eGFR of ≥ 60 mL/min/1.73m^2 (68%). A small proportion of patients had eGFR of < 30 mL/min/1.73m^2 (10%). Most of the patients who were admitted had a primary presenting diagnosis of Chronic Coronary Syndrome (45%) and Acute Coronary Syndrome (45%), either ST-elevation myocardial infarction (33%) or non-ST-elevation myocardial infarction (12%). The demographic of the study population is summarized in Table 1.

Table 1. Demographic and clinical profile of patients who underwent coronary angiography in UP-PGH in 2019

Characteristics	Frequency (%) (N=515)
Age	
>50	393 (76%)
≤50	122 (24%)
Mean ± SD	57.47 ± 9.91 years
Sex	
Female	133 (26%)
Male	382 (74%)
Type of Admission	
Elective	319 (62%)
Emergency	196 (38%)
Chief Complaint	
Chest pain or angina	419 (81%)
Dyspnea or exertional dyspnea	73 (14%)
Pre-operative evaluation prior to cardiovascular surgery	13 (23%) 6 (1%)
Loss of consciousness	4 (0.8%)
Pre-employment evaluation	
Estimated GFR on admission (in mL/in/1.73m^2)	
<30	51 (10%)
30-59	104 (20%)
≥60	348 (68%)
No data available	12 (2%)
Primary Presenting Diagnosis (n=513)	
Chronic Coronary Syndrome (CCS)	231 (45%)
Acute Coronary Syndrome (ACS)	233 (45%)
STEMI	171 (33%)
NSTEMI	62 (12%)
Heart Failure	14 (3%)
Valvular Heart Disease	23 (4%)
Others	14 (3%)

Indications for Coronary Angiography

We classified the indications for CA performed based on their 2012 AUC score. Our findings showed that 99.8% of the CA performed were appropriate, of which majority (54%) had an AUC score of A9 (Table 2). Table 3 shows the frequency of each specific indications and their corresponding AUC score. STEMI or a suspicion of STEMI was the most commonly encountered (33%) with an AUC score of A9. The frequency of specific indications based on ACC/AHA Class of Recommendation is in Appendix D.

Table 2. Appropriateness of use criteria (AUC) among patients who underwent coronary angiography

Appropriateness of Coronary Angiogram	N=515	%
Appropriate	514	99.8%
7	105	20%
8	132	26%
9	277	54%
Uncertain	1	0.2%
Inappropriate	0	0

Angiographic Profile

Of the 515 coronary angiograms analyzed, we observed that 74 (14%) were normal, and 55 (11%) had non-obstructive CAD. Majority of the CA studies showed obstructive CAD (75%). Among these, 19% had single-vessel CAD, 18% had two-vessel CAD and 38% had three-vessel CAD. The most commonly affected vessel was the left anterior descending artery. This was followed by the right coronary artery and left circumflex artery. There was note of left main disease in 27% of all patients with obstructive CAD. Table 4 provides a summary of the angiographic profile.

Table 5 showed that that majority of patients with obstructive CAD were >50 years of age (77%), males (80%) and have ACS on admission (89%). Although majority of the females were still found to have obstructive CAD (59%), normal CA findings were more common among the females (29%) than in males (9%). Also, normal CA findings were more common among patients who had elective CA (20%), and patients with valvular heart disease (65%). This table also showed that majority of the patients with eGFR of <30 have obstructive CAD (76%). Among patients with chronic coronary syndrome (CCS) and ACS, majority of the patients with obstructive CAD had 3-vessel disease, at 35% and 43%, respectively (Appendix E).

Non-invasive Tests Prior to Angiography

Table 6 summarizes the non-invasive tests done in the included patients in this study. A total of 349 (68%) patients

Table 3. Frequency of specific indications for coronary angiography and their corresponding AUC score

AUC Score	Indication	N=515	%
A9	STEMI or suspected STEMI	171	33.2
A9	UA/NSTEMI with high-risk score (e.g., TIMI, GRACE)	44	8.54
A9	Patients With Known Obstructive CAD (e.g., Prior MI, Prior PCI, Prior CABG, or Obstructive Disease on Invasive Angiography) Medically Managed Patients High-risk noninvasive findings Worsening or Limiting Symptoms AND Worsening Findings	41	7.96
A9	Stress Test With Imaging (SPECT MPI, Stress Echocardiography, Stress PET, Stress CMR) High-risk findings (e.g., >10% ischemic myocardium on stress SPECT MPI or stress PET, stress-induced wall motion abnormality in 2 or more segments on stress echo or stress CMR), symptomatic	13	2.52
A9	ECG Stress Testing Other high-risk findings (ST-segment elevation, hypotension with exercise, ventricular tachycardia, prolonged ST-segment depression), symptomatic	5	0.97
A9	Cardiogenic shock due to suspected ACS	2	0.39
A9	Suspected significant ischemic complication related to CAD (e.g., ischemic mitral regurgitation or VSD)	1	0.19
A8	Newly recognized LV systolic dysfunction (i.e., LVEF 41% to 49%) with an unknown etiology on Echocardiography, symptomatic	46	8.93
A8	Newly recognized LV systolic dysfunction on Echocardiography TTE (i.e., LVEF ≤40%) with an unknown etiology, symptomatic	39	7.57
A8	Pulmonary Hypertension or Intracardiac Shunt Evaluation Known or suspected intracardiac shunt with indeterminate shunt anatomy or shunt fraction	14	2.72
A8	Patients With Known Obstructive CAD (e.g., Prior MI, Prior PCI, Prior CABG, or Obstructive Disease on Invasive Angiography) Post Revascularization (PCI or CABG) High-risk noninvasive findings Worsening or limiting symptoms	11	2.14
A8	ECG Stress Testing, High-risk findings (e.g., Duke treadmill score ≤11), symptomatic	10	1.94
A8	UA/NSTEMI with intermediate-risk score (e.g., TIMI, GRACE)	9	1.75
A8	Arrhythmias Etiology Unclear After Initial Evaluation Resuscitated cardiac arrest with return of spontaneous circulation	2	0.39
A8	Evidence (e.g., PET, CMR, delayed thallium uptake, dobutamine echo) of myocardial viability in Baseline resting LV dysfunction (i.e., LVEF ≤40%) AND dysfunctional segment, symptomatic	1	0.19
A7	New regional wall motion abnormality with an unknown etiology and normal LV systolic function, symptomatic	38	7.38
A7	Valvular Disease: Preoperative assessment before valvular surgery	22	4.27
A7	Suspected CAD: No Prior Noninvasive Stress Imaging (No Prior PCI, CABG, or Angiogram Showing >50% Angiographic Stenosis) Symptomatic with High Pretest Probability	20	3.88
A7	ECG Stress Testing, High-risk findings (e.g., Duke treadmill score ≤11), asymptomatic	7	1.36
A7	UA/NSTEMI with Low-risk score (e.g., TIMI, GRACE)	4	0.78
A7	Suspected pulmonary artery hypertension, Equivocal or borderline elevated estimated right ventricular systolic pressure on resting echo study	4	0.78
A7	Patients With Known Obstructive CAD (e.g., Prior MI, Prior PCI, Prior CABG, or Obstructive Disease on Invasive Angiography) Post Revascularization (PCI or CABG) Intermediate-risk noninvasive findings Worsening or limiting symptoms	3	0.58
A7	Adjunctive Invasive Diagnostic Testing in Patients Undergoing Appropriate Diagnostic Coronary Angiography FFR for Lesion Severity Angiographically intermediate disease (non-left main) 50% to 69%, Prior testing = concordant ischemic findings	2	0.39
A7	Patients With Known Obstructive CAD (e.g., Prior MI, Prior PCI, Prior CABG, or Obstructive Disease on Invasive Angiography), Intermediate non-invasive with Worsening or Limiting Symptoms AND Worsening Findings	2	0.39
A7	Suspected ACS with newly diagnosed LV wall motion abnormality or newly diagnosed resting myocardial perfusion defect with a Low-Risk score	1	0.19
A7	Stress Test With Imaging (SPECT MPI, Stress Echocardiography, Stress PET, Stress CMR) Discordant findings (e.g., low-risk prior imaging with ongoing symptoms consistent with ischemic equivalent)	1	0.19
A7	Adjunctive Invasive Diagnostic Testing in Patients Undergoing Appropriate Diagnostic Coronary Angiography FFR for Lesion Severity Angiographically intermediate disease (non-left main) 50% to 69%, Prior testing = no ischemic findings	1	0.19
U4	Low-risk TET findings, symptomatic	1	0.19

had non-invasive testing done prior to doing coronary angiogram while 164 (32%) did not have prior non-invasive testing. Majority of the non-invasive tests done were resting 2D echocardiogram (86%) followed by myocardial perfusion imaging (9%) and stress test (3%). Among the patients who did not have non-invasive testing, 98% were classified as needing emergency coronary angiogram.

As shown in Table 7, among those who underwent non-invasive testing, 312 (89%) had abnormal results. Overall, almost 73% of those with abnormal non-invasive findings

Table 4. Angiographic profile of patients who underwent coronary angiography (N=515)

Angiographic Profile	n (Frequency %)
Obstructive CAD	**386 (75%)**
Severe 1V CAD	99 (19%)
Severe 2V CAD	92 (18%)
Severe 3V CAD	194 (38%)
Isolated Left Main	1 (0.19%)
Normal	**74 (14%)**
Non-obstructive CAD	**55 (11%)**
Lesions with Significant Stenosis	
Left main coronary artery (LMCA)	106
Left anterior descending artery (LAD)	356
Left circumflex artery (LCx)	244
Right coronary artery (RCA)	276

Table 5. Patient characteristics based on coronary angiography findings of patients

Characteristics	Normal N=74	Non-obstructive N=55	Obstructive N=386
Age >50	49 (13%)	40 (10%)	304 (77%)
Male	35 (9%)	40 (10%)	307 (80%)
Female	39 (29%)	15 (11%)	79 (59%)
Elective	63 (20%)	45 (14%)	211 (66%)
Emergency	11 (6%)	10 (5%)	175 (89%)
Primary Diagnosis on Admission			
ACS	17 (7%)	9 (4%)	207(89%)
STEMI	7 (4%)	5 (3%)	159 (93%)
NSTEMI	10 (16%)	4 (6%)	48 (77%)
CCS	37 (16%)	37 (16%)	157 (68%)
Heart Failure	3 (21%)	3 (21%))	8 (57%)
Valvular	15 (65%)	4 (17%)	4 (17%)
Preop evaluation	2 (14%)	2 (14%)	10(71%)
eGFR			
<30	6 (12%)	6 (12%)	39(76%)
30-59	10 (10%)	8 (8%)	86 (83%)
≥60	54 (16%)	39 (11%)	255 (73%)

Table 6. Summary of non-invasive tests done prior to coronary angiography of patients who underwent coronary angiography

	N=515 (100%)
Non-Invasive Test Done	349 (68%)
Resting 2D Echocardiogram	300 (86%)
Myocardial Perfusion Imaging	32 (9%)
Stress Test	11 (3%)
Stress 2D Echocardiogram	5 (1%)
Coronary CT Angiography	1 (0.02%)
No Tests Done	164 (32%)
No Data	2 (0.4%)

Table 7. Summary of non-invasive and invasive findings

Invasive / Angiographic findings	Non-invasive findings	
	Abnormal findings n=312 (89%)	Normal findings n=37 (11 %)
Normal	45 (14%)	18 (49%)
Non-Obstructive CAD	40 (13%)	8 (22%)
1-vessel CAD	54 (17%)	3 (8%)
2-vessel CAD	50 (16%)	1 (3%)
3-vessel CAD	123 (39%)	7 (20%)

had significant CAD (1-, 2-, 3-vessel CAD) while around 27% had either normal coronaries or non-obstructive CAD. Three vessel CAD was most prevalent among those with abnormal non-invasive tests.

DISCUSSION

CA is an important diagnostic tool in the diagnosis and management of CAD around the world. However, while its utility is well established, the cost of CA is a strong limitation for its wide utilization. In UP-PGH, a tertiary government hospital whose patients belong to the lowest economic classes, physicians are hard-pressed to ensure that each procedure is performed appropriately with the right balance between cost and effectiveness. It is also important to note that the UP-PGH is one of the few PCI-capable tertiary hospitals in the City of Manila, with patients served as far as the provinces in the south of Metro Manila. This study aimed to look at the appropriateness of the CA performed in UP-PGH. To the best of our knowledge, there are no published data regarding the clinical and angiographic profiles of patients undergoing coronary angiography in a government institution in the Philippines.

We have found that majority of the CA studies performed in our cardiac catheterization laboratory for the year 2019 were executed based on highly appropriate indications (AUC scores A7 to A9). The most common indication to perform CA was STEMI or a suspicion of STEMI, with an AUC score of A9. There is only one other study done in the country investigating AUC of CA in a hospital setting. Our study showed a higher percentage of appropriate indications (99%) compared to 86% in a local retrospective case series. It is also noteworthy that we only had 1 CA done (0.19%) with an uncertain indication. The 1 patient in our study who underwent CA despite an AUC score of U4 was a diabetic with prior NSTEMI who had normal resting 2D-echocardiogram findings but with equivocal treadmill exercise test (TET). In comparison, 11% of the indications for CA done in the study by Hipe et al were uncertain. In almost all cases, our institution have performed CA with a high degree of appropriateness.

These findings are significant and encouraging as they reflect well on our laboratory's performance in terms of service delivery to the appropriate population base. The status of our institution, being a government tertiary referral center, may be contributory to this. Our pool of patients consists mostly of referrals from primary care physicians or health centers for cardiology consultation. Hence, the baseline likelihood of them needing advanced forms of cardiac evaluation, such as CA, would understandably be higher compared to the general population. Also, with PGH being a training institution with both a cardiology fellowship program and an Internal Medicine residency program, we follow a well-structured referral system with several checkpoints before sending a patient for CA. A documented

workflow is utilized by trainees when referring patients for coronary angiography. In all cases, a CA will be scheduled with the final approval by the consultant in charge. These guidelines help ensure the appropriateness of the indications for CA among our patients.

Establishing performance-based evidence in performing appropriate CA in our patients also has implications on our utilization of government funds. These data may be used as robust basis for requests for continued government budget allocation to fund and upgrade operations of our cardiac catheterization laboratory. As of this writing, UP-PGH is one of the two government hospitals that provides subsidized CA for patients in the country. Because of this, there is a need to balance allocation of funds and resources with the cost effectiveness of this procedure.

This study presented similar demographic profiles with those of previous AUC studies on the performance of CA. Profiles of our patients were comparable with local data reported. The mean age of the patients in this study (57.47 ± 9.91 years old) was similar to the patients in the local study (58.4 ± 10.9 years old).[9] Likewise, patients in both studies were predominantly male. Among published data from other countries, reported mean age are as follows: 61.6 (Brazil), 61.8 (United States) and 63.6 (Canada). In the local study as well as foreign data mentioned above, the patients were predominantly male, like this study population.

Most of our patients presented with chest pain or angina. This is not surprising given that majority of the indications for CA as shown in our study were acute or chronic coronary syndromes, of which chest pain is the most common symptom.

Two-Dimensional Echocardiography was the most common non-invasive testing in the study population and further non-invasive testing were no longer done because of the following reasons: 1) severe abnormalities were already evident on the resting echocardiogram that would not warrant further stress tests, 2) high clinical probability of CAD already present, 3) high risk clinical presentation such as ACS, and 4) indication was for cardiac surgery preparation. Among the patients who did not undergo non-invasive testing prior to CA, 160 (98%) out of 164 were sent to cardiac catheterization laboratory as emergency ACS cases. Understandably, non-invasive tests were no longer performed in these cases to avoid delays in performing CA and subsequent time-dependent intervention. Despite the 2 echocardiogram results which were not retrieved, we were able to evaluate the appropriateness of CA in those patients using other clinical data, which showed that both patients remained symptomatic despite optimal medical therapy.

Abnormal non-invasive test such as 2D-echocardiography showing regional wall motion abnormality (RWMA) and decreased ejection fraction has been shown to impact the diagnosis of coronary artery disease.[10] Consistently, in this study, majority (73%) of those who had abnormal resting echocardiograms, stress tests, stress echocardiograms and myocardial perfusion imaging scans showed significant CAD.

However, it is significant to recognize that 27% had normal or non-obstructive CAD despite abnormal non-invasive test results. An increasingly reported condition among these patients with anginal symptoms and abnormal non-invasive test but normal or non-significant CAD is microvascular dysfunction (MCD).[11] MCD was previously thought to be benign but recent studies have shown that it has a 2.5% annual risk of major adverse cardiac events.[12] Therefore, these subset of patients of IHD should not be neglected and should be treated accordingly.

Majority of the patients with normal non-invasive results who had normal CA findings were patients for open heart surgery, such as valvular repair or replacement or cardiac tumor excision. Meanwhile, the rest of the patients with normal resting echocardiogram had significant CAD. As pointed out in several studies, a normal resting echocardiogram has a poor sensitivity to rule out CAD hence stress modalities to detect functional ischemia are recommended.[13]

The rate of normal and non-obstructive CA are two important performance metrics to ensure quality of care in a cardiac catheterization laboratory. The ACC/SCAI Expert Consensus guideline recommends that the rate of normal CA should be in the range of 20% to 27% and the rate of non-obstructive disease in elective patients be less than 40% after proper screening of patients.[14,15] The percentage of normal and non-obstructive CAD varies among different cardiac catheterization laboratories, ranging from 15.1%-48.5%, as reported in international registries.[16,17] In our institution, 14% had normal coronaries and 11% had non-obstructive CAD. These results were similar to the local retrospective study which showed 15.5% normal coronaries and 13% had non-obstructive CAD.[9] Compared with a US study done, our study showed lower normal coronary rates 14% compared to 39% in a study done using the ACC/ NCDR registry.[17] This study also showed a greater proportion of 3-vessel CAD (38%) among patients who underwent CA in our institution compared with 18.6% in a US registry.[16] The artery most commonly affected in this study was the left anterior descending artery, with CCS (47%) and ACS (43%) as the most common indications for CA. These findings are also comparable to the aforementioned local study.

The lower rate of the normal coronaries and non-obstructive CAD along with higher rate of patients with positive non-invasive tests and obstructive CAD (75%) may indicate higher risk group of patients who underwent CA and may indicate physician's appropriate and selective use of the CA procedure.[9,16,17]

Limitation of the Study

One limitation of this study, which was inherent to our methods utilizing a review of the cardiac catheterization laboratory database, was that collected data was based on

what was available in the database. Two echocardiogram reports were not available, but we were still able to evaluate the appropriateness of CA in those patients using other clinical data. To remedy this, at least 3 authors reviewed the data for adjudication.

CONCLUSION

Majority (99%) of the CA studies performed among adult service patients in the PGH cardiac catheterization laboratory for the year 2019 were executed based on highly appropriate indications (AUC scores A7 to A9). Among the specific indications, STEMI or a suspicion of STEMI was the most common and frequently encountered at 33% of the time. Almost three fourths of our patients (75%) had obstructive Coronary Artery Disease (CAD), with left anterior descending artery as the most frequently involved vessel. *Based on the data generated from this study, the government's allocation of resources and funds are deemed to be well-utilized.*

Statement of Authorship

All authors participated in data collection and analysis, and approved the final version submitted.

Author Disclosure

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APPENDICES

Appendix A. CCF/SCAI/AATS/AHA/ASE/ASNC/HFSA/HRS/SCCM/SCCT/SCMR/STS 2012 Appropriate Use Criteria for Diagnostic Catheterization Diagnostic Catheterization[6]

Appropriate Use Criteria (by Appropriate Use Rating)

Table 1. *Appropriate Indications (Median Score 7–9)*

Indication		Appropriate Use Score (1–9)
23.	• Baseline resting LV dysfunction (i.e., LVEF ≤40%) AND • Evidence (e.g., PET, CMR, delayed thallium uptake, dobutamine echo) of myocardial viability in dysfunctional segment • Asymptomatic	A (7)
23.	• Baseline resting LV dysfunction (i.e., LVEF ≤40%) AND • Evidence (e.g., PET, CMR, delayed thallium uptake, dobutamine echo) of myocardial viability in dysfunctional segment • Symptomatic	A (8)
	Echocardiography (TTE)	
24.	• Newly recognized LV systolic dysfunction (i.e., LVEF ≤40%) with an unknown etiology • Symptomatic	A (8)
25.	• Newly recognized LV systolic dysfunction (i.e., LVEF 41% to 49%) with an unknown etiology • Symptomatic	A (8)
26.	• New regional wall motion abnormality with an unknown etiology and normal LV systolic function • Symptomatic	A (7)
27.	• Suspected significant ischemic complication related to CAD (e.g., ischemic mitral regurgitation or VSD)	A (9)
	Coronary CTA	
33.	• Lesion ≥50% non-left main • Symptomatic	A (7)
34.	• Lesion ≥50% left main • Symptomatic	A (8)
35.	• Lesions ≥50% in more than 1 coronary territory • Symptomatic	A (7)
36.	• Lesion of unclear severity, possibly obstructive (non-left main) • Symptomatic	A (7)
37.	• Lesion of unclear severity, possibly obstructive (left main) • Asymptomatic	A (7)
37.	• Lesion of unclear severity, possibly obstructive (left main) • Symptomatic	A (8)
	Adjunctive Invasive Diagnostic Testing in Patients Undergoing Appropriate Diagnostic Coronary Angiography	
	FFR for Lesion Severity	
40.	• Angiographically indeterminate severity left main stenosis (defined as 2 or more orthogonal views contradictory whether stenosis >50%) • Unexpected angiographic finding or no prior noninvasive testing	A (7)
40.	• Angiographically indeterminate severity left main stenosis (defined as 2 or more orthogonal views contradictory whether stenosis >50%) • Prior testing = no ischemic findings	A (7)
40.	• Angiographically indeterminate severity left main stenosis (defined as 2 or more orthogonal views contradictory whether stenosis >50%) • Prior testing = concordant ischemic findings	A (7)
42.	• Angiographically intermediate disease (non-left main) 50% to 69% • Unexpected angiographic finding or no prior noninvasive testing	A (7)
42.	• Angiographically intermediate disease (non-left main) 50% to 69% • Prior testing = concordant ischemic findings	A (7)
43.	• Angiographically obstructive significant disease (non-left main) ≥70% stenosis • Unexpected angiographic finding or no prior noninvasive testing	A (7)
43.	• Angiographically obstructive significant disease (non-left main) ≥70% stenosis • Prior testing = no ischemic findings	A (7)

Table 1. *Appropriate Indications (Median Score 7–9) (continued)*

Indication		Appropriate Use Score (1–9)
IVUS for Lesion Severity		
44.	• Angiographically indeterminate severity left main stenosis (defined as 2 or more orthogonal views contradictory whether stenosis >50%) • Unexpected angiographic finding or no prior noninvasive testing	A (7)
44.	• Angiographically indeterminate severity left main stenosis (defined as 2 or more orthogonal views contradictory whether stenosis >50%) • Prior testing = no ischemic findings	A (7)
44.	• Angiographically indeterminate severity left main stenosis (defined as 2 or more orthogonal views contradictory whether stenosis >50%) • Prior testing = concordant ischemic findings	A (7)
IVUS—Examination of Lesion or Artery Morphology		
48.	• Coronary lesions or structures difficult to characterize angiographically (e.g., aneurysm, extent of calcification, stent fracture, stent apposition, stent expansion, dissections) or for sizing of vessel before stent placement	A (8)
Patients With Known Obstructive CAD (e.g., Prior MI, Prior PCI, Prior CABG, or Obstructive Disease on Invasive Angiography)		
Medically Managed Patients		
50.	• Intermediate-risk noninvasive findings • Worsening or limiting symptoms and worsening findings	A (7)
51.	• High-risk noninvasive findings • Asymptomatic/controlled symptoms or unchanged findings	A (7)
51.	• High-risk noninvasive findings • Worsening or limiting symptoms and worsening findings	A (9)
Post Revascularization (PCI or CABG)		
54.	• Intermediate-risk noninvasive findings • Worsening or limiting symptoms	A (7)
55.	• High-risk noninvasive findings • Worsening or limiting symptoms	A (8)
Arrhythmias		
Etiology Unclear After Initial Evaluation		
57.	• Resuscitated cardiac arrest with return of spontaneous circulation	A (8)
58.	• VF or sustained VT with or without symptoms	A (8)
Valvular Disease		
70.	• Preoperative assessment before valvular surgery	A (7)
71.	• Pulmonary hypertension out of proportion to the severity of valvular disease	A (8)
72.	• Left ventricular dysfunction out of proportion to the severity of valvular disease	A (8)
Chronic Native or Prosthetic Valvular Disease Symptomatic Related to Valvular Disease		
81.	• Mild or moderate mitral stenosis • Noninvasive imaging for valvular disease conflicting with clinical impression of severity	A (7)
82.	• Severe mitral stenosis • Noninvasive imaging for valvular disease conflicting with clinical impression of severity	A (7)
83.	• Mild or moderate mitral regurgitation • Noninvasive imaging for valvular disease conflicting with clinical impression of severity	A (7)
84.	• Severe mitral regurgitation • Noninvasive imaging for valvular disease conflicting with clinical impression of severity	A (7)
85.	• Mild or moderate aortic stenosis • Noninvasive imaging for valvular disease conflicting with clinical impression of severity	A (7)
86.	• Severe aortic stenosis • Noninvasive imaging for valvular disease conflicting with clinical impression of severity	A (8)
87.	• Equivocal aortic stenosis/low gradient aortic stenosis • May include pharmacological challenge (e.g., dobutamine) • Noninvasive imaging for valvular disease conflicting with clinical impression of severity	A (8)
88.	• Mild or moderate aortic regurgitation • Noninvasive imaging for valvular disease conflicting with clinical impression of severity	A (7)
89.	• Severe aortic regurgitation • Noninvasive imaging for valvular disease conflicting with clinical impression of severity	A (8)
90.	• Acute moderate or severe mitral or aortic regurgitation • Noninvasive imaging for valvular disease conflicting with clinical impression of severity	A (8)

Table 1. *Appropriate Indications (Median Score 7–9) (continued)*

Indication		Appropriate Use Score (1–9)
Pericardial Diseases		
91.	• Suspected pericardial tamponade	A (8)
92.	• Suspected or clinical uncertainty between constrictive vs. restrictive physiology	A (8)
Cardiomyopathies		
93.	• Known or suspected cardiomyopathy with or without heart failure	A (7)
94.	• Re-evaluation of known cardiomyopathy • Change in clinical status or cardiac exam or to guide therapy	A (7)
Pulmonary Hypertension or Intracardiac Shunt Evaluation		
96.	• Known or suspected intracardiac shunt with indeterminate shunt anatomy or shunt fraction	A (8)
Evaluation of Pulmonary Hypertension		
97.	• Suspected pulmonary artery hypertension • Equivocal or borderline elevated estimated right ventricular systolic pressure on resting echo study	A (7)
98.	• Suspected pulmonary hypertension • Elevated estimated right ventricular systolic pressure on resting echo study	A (7)
99.	• Resting pulmonary hypertension • Determine response to pulmonary vasodilators given in cath lab	A (8)
100.	• Resting pulmonary hypertension • Determine response after initiation of drug therapy	A (7)
101.	• Post heart transplant patient • With or without the performance of endomyocardial biopsy	A (7)
102.	• Indeterminate intravascular volume status • Etiology unclear after initial evaluation	A (7)

A = appropriate; ACS = acute coronary syndrome; CABG = coronary bypass grafting surgery; CAD = coronary artery disease; CMR = cardiovascular magnetic resonance; CTA = computed tomography angiography; ECG = electrocardiogram; FFR = fractional flow reserve; GRACE = Global Registry of Acute Coronary Events; IVUS = intravascular ultrasound; LV = left ventricular; LVEF = left ventricular ejection fraction; MI = myocardial infarction; PET = positron emission tomography; PCI = percutaneous coronary intervention; SPECT MPI = single-photon emission computed tomography myocardial perfusion imaging; STEMI = ST-elevation myocardial infarction; TID = transient ischemic dilation; TIMI = Thrombolysis In Myocardial Infarction; TTE = transthoracic echocardiography; UA/NSTEMI = unstable angina/non–ST-elevation myocardial infarction; VF = ventricular fibrillation; VSD = ventricular septal defect; VT = ventricular tachycardia.

Table 2. *Uncertain Indications (Median Score 4–6)*

Indication		Appropriate Use Score (1–9)
Suspected CAD: No Prior Noninvasive Stress Imaging (No Prior PCI, CABG, or Angiogram Showing ≥50% Angiographic Stenosis)		
7.	• High global CAD risk • Asymptomatic	U (4)
9.	• Intermediate pretest probability • Symptomatic	U (6)
Suspected CAD: Prior Noninvasive Testing (No Prior PCI, CABG, or Angiogram Showing ≥50% Angiographic Stenosis)		
ECG Stress Testing		
11.	• Low-risk findings (e.g., Duke treadmill score ≥5) • Symptomatic	U (4)
12.	• Intermediate-risk findings (e.g., Duke treadmill score 4 to −10) • Asymptomatic	U (4)
12.	• Intermediate-risk findings (e.g., Duke treadmill score 4 to −10) • Symptomatic	U (6)
Stress Test With Imaging (SPECT MPI, Stress Echocardiography, Stress PET, Stress CMR)		
15.	• Low-risk findings (e.g., <5% ischemic myocardium on stress SPECT MPI or stress PET, no stress-induced wall motion abnormalities on stress echo or stress CMR) • Symptomatic	U (4)
16.	• Intermediate-risk findings (e.g., 5% to 10% ischemic myocardium on stress SPECT MPI or stress PET, stress-induced wall motion abnormality in a single segment on stress echo or stress CMR) • Asymptomatic	U (4)
20.	• Discordant findings (e.g., low-risk stress imaging with high-risk stress ECG response or stress-induced typical angina) • Asymptomatic	U (5)
21.	• Equivocal/uninterpretable findings (e.g., perfusion defect vs. attenuation artifact, uninterpretable stress imaging) • Asymptomatic	U (5)

Table 2. *Uncertain Indications (Median Score 4–6) (continued)*

	Indication	Appropriate Use Score (1–9)
	Stress Test With Imaging (SPECT MPI, Stress Echocardiography, Stress PET, Stress CMR)	
22.	• Fixed perfusion defect on SPECT MPI or a persistent wall motion abnormality on stress echo consistent with infarction without significant ischemia (<5% ischemic myocardium) • Asymptomatic	U (4)
22.	• Fixed perfusion defect on SPECT MPI or a persistent wall motion abnormality on stress echo consistent with infarction without significant ischemia (<5% ischemic myocardium) • Symptomatic	U (6)
	Echocardiography (TTE)	
24.	• Newly recognized LV systolic dysfunction (i.e., LVEF ≤40%) with an unknown etiology • Asymptomatic	U (6)
25.	• Newly recognized LV systolic dysfunction (i.e., LVEF 41% to 49%) with an unknown etiology • Asymptomatic	U (5)
26.	• New regional wall motion abnormality with an unknown etiology and normal LV systolic function • Asymptomatic	U (5)
	Coronary CTA	
32.	• Lesion <50% non-left main • Symptomatic	U (4)
33.	• Lesion ≥50% non-left main • Asymptomatic	U (4)
35.	• Lesions ≥50% in more than 1 coronary territory • Asymptomatic	U (5)
36.	• Lesion of unclear severity, possibly obstructive (non-left main) • Asymptomatic	U (4)
38.	• Lesion <50% with extensive partly calcified and noncalcified plaque • Symptomatic	U (5)
	Adjunctive Invasive Diagnostic Testing in Patients Undergoing Appropriate Diagnostic Coronary Angiography	
	FFR for Lesion Severity	
41.	• Nonobstructive disease by angiography (non-left main) <50% • Prior testing = concordant ischemic findings	U (5)
42.	• Angiographically intermediate disease (non-left main) 50% to 69% • Prior testing = no ischemic findings	U (6)
	IVUS for Lesion Severity	
45.	• Non-obstructive disease by angiography (non-left main) <50% • Prior testing = concordant ischemic findings	U (6)
46.	• Angiographically intermediate disease (non-left main) 50% to 69% • Unexpected angiographic finding or no prior noninvasive testing	U (5)
46.	• Angiographically intermediate disease (non-left main) 50% to 69% • Prior testing = no ischemic findings	U (5)
46.	• Angiographically intermediate disease (non-left main) 50% to 69% • Prior testing = concordant ischemic findings	U (6)
47.	• Angiographically obstructive significant disease (non-left main) ≥70% stenosis • Unexpected angiographic finding or no prior noninvasive testing	U (4)
47.	• Angiographically obstructive significant disease (non-left main) ≥70% stenosis • Prior testing = no ischemic findings	U (5)
	Patients With Known Obstructive CAD (e.g., Prior MI, Prior PCI, Prior CABG, or Obstructive Disease on Invasive Angiography)	
	Medically Managed Patients	
49.	• Low-risk noninvasive findings • Worsening or limiting symptoms and worsening findings	U (6)
50.	• Intermediate-risk noninvasive findings • Asymptomatic/controlled symptoms or unchanged findings	U (4)
	Post Revascularization (PCI or CABG)	
53.	• Low-risk noninvasive findings • Worsening or limiting symptoms	U (6)
	Post Revascularization (PCI)	
56.	• Asymptomatic • Prior unprotected left main PCI	U (5)

Table 2. *Uncertain Indications (Median Score 4–6) (continued)*

	Indication	Appropriate Use Score (1–9)
	Arrhythmias	
	Etiology Unclear After Initial Evaluation	
59.	• Nonsustained VT (<6 beats VT) • Normal LV systolic function	U (5)
	No Prior Noninvasive Assessment of Ischemia With Normal Systolic Function	
60.	• Syncope • Intermediate CHD risk	U (4)
60.	• Syncope • High CHD risk	U (6)
61.	• New-onset atrial fibrillation or flutter • High CHD risk	U (5)
62.	• Heart block (e.g., second-degree type II or third-degree AV block) OR • Symptomatic bradyarrhythmias • High CHD risk	U (5)
63.	• Newly diagnosed LBBB • Low CHD risk	U (4)
63.	• Newly diagnosed LBBB • Intermediate CHD risk	U (5)
63.	• Newly diagnosed LBBB • High CHD risk	U (6)
	Preoperative Coronary Evaluation for Noncardiac Surgery in Stable Patients	
66.	• Prior to solid organ transplantation	U (5)
	<4 METS Functional Capacity, No Noninvasive Testing Performed, With or Without Clinical Risk Factors Present (Preoperative Clinical Risk Factors: Ischemic Heart Disease, Heart Failure, Cerebrovascular Disease, Insulin-Requiring Diabetes Mellitus, Renal Insufficiency Cr >2.0)	
68.	• 1 to 2 risk factors • Vascular surgery	U (4)
69.	• ≥3 risk factors • Intermediate-risk surgery	U (4)
69.	• ≥3 risk factors • Vascular surgery	U (6)
	Valvular Disease	
	Chronic Native or Prosthetic Valvular Disease Asymptomatic Related to Valvular Disease	
74.	• Severe mitral stenosis	U (6)
76.	• Severe mitral regurgitation	U (5)
78.	• Severe aortic stenosis	U (4)
80.	• Severe aortic regurgitation	U (5)
	Chronic Native or Prosthetic Valvular Disease Symptomatic Related to Valvular Disease	
90.	• Acute moderate or severe mitral or aortic regurgitation • Noninvasive imaging for valvular disease concordant with clinical impression of severity	U (4)
	Cardiomyopathies	
95.	• Suspected arrhythmogenic right ventricular dysplasia • Assessment of right ventricular morphology	U (5)

AV = atrioventricular; CABG = coronary bypass grafting surgery; CAD = coronary artery disease; CHD = coronary heart disease; CMR = cardiovascular magnetic resonance; Cr = creatinine; CTA = computed tomography angiography; ECG = electrocardiogram; FFR = fractional flow reserve; IVUS = intravascular ultrasound; LBBB = left bundle branch block; LV = left ventricular; LVEF = left ventricular ejection fraction; METS = metabolic equivalents; MI = myocardial infarction; PCI = percutaneous coronary intervention; PET = positron emission tomography; SPECT MPI = single-photon emission computed tomography myocardial perfusion imaging; TTE = transthoracic echocardiography; U = uncertain; VT = ventricular tachycardia.

Table 3. *Inappropriate Indications (Median Score 1–3)*

	Indication	Appropriate Use Score (1–9)
Suspected CAD: No Prior Noninvasive Stress Imaging (No Prior PCI, CABG, or Angiogram Showing ≥50% Angiographic Stenosis)		
5.	• Low global CAD risk • Asymptomatic	I (1)
6.	• Intermediate global CAD risk • Asymptomatic	I (3)
8.	• Low pretest probability • Symptomatic	I (3)
Suspected CAD: Prior Noninvasive Testing (No Prior PCI, CABG, or Angiogram Showing ≥50% Angiographic Stenosis)		
ECG Stress Testing		
11.	• Low-risk findings (e.g., Duke treadmill score ≥5) • Asymptomatic	I (1)
Stress Test With Imaging (SPECT MPI, Stress Echocardiography, Stress PET, Stress CMR)		
15.	• Low-risk findings (e.g., <5% ischemic myocardium on stress SPECT MPI or stress PET, no stress-induced wall motion abnormalities on stress echo or stress CMR) • Asymptomatic	I (2)
Coronary Calcium Score		
28.	• Agatston score <100 • Asymptomatic	I (1)
29.	• Agatston score 100 to 400 • Asymptomatic	I (2)
30.	• Agatston score 400–1,000 • Asymptomatic	I (3)

Appendix B. Operational definitions

Term	Definition
Age	Age in years; an age > 50 years is considered as a risk factor for CAD in this study.
Elective	A CA done in patients who were admitted as walk-in patients at the wards for a scheduled CA procedure
Emergency	A CA done in patients who were admitted for emergent or urgent medical conditions
Ejection fraction (EF)	Ejection fraction is defined as stroke volume divided by the left ventricular end-diastolic volume. In this study, the recorded EF is derived from 2D echocardiography. A normal EF is defined as >50%; Mild to Moderately Depressed (30-50%); Severely depressed (<30%)
Estimated Glomerular Filtration Rate (eGFR)	Measurement of renal function, as calculated based on the Chronic Kidney Disease Epidemiology Collaboration (CKD-EPI) equation
Unstable Angina	Patients without typical anginal symptoms and serial negative markers of myocardial necrosis.
Non-ST Elevation Myocardial Infarction (NSTEMI)	Patients with typical anginal symptoms without persistent ST elevation in at least 2 contiguous electrocardiographic leads but with elevation of myocardial biomarkers >99% of normal.
ST Elevation Myocardial Infarction (STEMI)	Patients with clinical presentation of angina or anginal equivalents and the electrocardiographic criteria (by voltage and contiguous distribution) as diagnosed by the attending physician at the ER
Coronary angiogram findings:	
Normal	< 20% angiographic stenosis
Non-obstructive CAD	Angiographic stenosis >20% but < 50% in left main and stenosis of >20% but <70% on other coronary arteries.
Obstructive CAD	Angiographic stenosis 50% in left main and stenosis of >70% on other coronary arteries.
Non-invasive findings:	
Normal	• For resting 2D echocardiogram: no wall motion abnormalities and ejection fraction preserved • For Stress Echocardiogram: no inducible wall motion abnormalities and no reduction of ejection fraction on stress • For Nuclear Imaging: no inducible ischemia, no ischemic segments, no infarcted segments and ejection fraction preserved and no reduction of ejection fraction on stress
Abnormal	• For CT Coronary Angiogram: no significant stenosis • For Treadmill Stress Test: no exercise-induced (1) ECG ischemic changes, (2) arrhythmia and (3) anginal chest pain • For resting 2D echocardiogram: presence of wall motion abnormalities and/or ejection fraction <50% • For Stress Echocardiogram: presence of inducible wall motion abnormalities and/or reduction of ejection fraction on stress • For Nuclear Imaging: presence of (1) inducible ischemia, (2) ischemic segments, (3) infarcted segments and/or (4) reduction ejection fraction preserved and/or reduction of ejection fraction on stress • For CT Coronary Angiogram: presence of significant stenosis • For Treadmill Stress Test: no exercise-induced (1) ECG ischemic changes, (2) arrhythmia and (3) anginal chest pain

Appendix C. Data collection sheet

Code: **Date admitted:**
Type of admission: **Date of procedure:**

Clinical profile:

BMI		Chief Complaint		
Age / Sex		Indication for Coronary Angiogram		AUC:
Acute Coronary Syndrome?	◻ Yes (indicate diagnosis: ◻ Anterior STEMI ◻ Non-Anterior STEMI ◻ NSTEMI ◻ UA) ◻ No			
Renal Function	Creatinine _____		eGFR: _____	
Non-Invasive Test	◻ Done ◻ Stress / Exercise Test ◻ Stress Echo ◻ Nuclear ◻ CTA ◻ MRI ◻ With functional ischemia ◻ No functional ischemia ◻ Equivocal ◻ Not Done			
Angiogram Results	◻ Normal / non-obstructive CAD ◻ Severe 1V CAD ◻ Severe 2V CAD ◻ Severe 3V CAD ◻ With Left Main involvement			
Lesions with Significant Stenosis	◻ Right coronary artery (RCA) ◻ Left main coronary artery (LMCA) ◻ Left anterior descending artery (LAD) ◻ Left circumflex artery (LCx)			
Diagnosis	◻ Normal ◻ Non-Obstructive CAD ◻ 1V-CAD ◻ 2V-CAD ◻ 3V-CAD			

Appendix D. Frequency of specific indications for coronary angiography based on ACC/AHA class of recommendation

Indication	N=515	Frequency (%)
Class I		
Primary PCI should be performed in patients with STEMI and ischemic symptoms of less than 12 hours' duration	107	21
SIHD whose characteristics and noninvasive testing indicate a high likelihood of severe IHD	61	12
Presumed SIHD who have unacceptable ischemic symptoms despite optimal medical therapy who are amenable to and candidates for coronary revascularization	43	8
SIHD who develop signs and symptoms of HF should be evaluated to determine whether coronary angiography should be performed for risk assessment	42	8
Immediate angiography and PCI when indicated should be performed in resuscitated out-of-hospital cardiac arrest patients whose initial ECG shows STEMI	28	5
Early invasive for initially stabilized UA/ NSTEMI who have an elevated risk for clinical events	26	5
After STEMI: Spontaneous ischemia or ischemia provoked with minimal exertion	14	3
CHF due to systolic dysfunction with angina or with regional wall motion abnormalities and/or scintigraphic evidence of reversible myocardial ischemia when revascularization is being considered	14	3
UA and NSTEMI Early invasive for refractory angina or hemodynamic / electrical instability	13	3
Valve Surgery- Before valve surgery in an adult free of chest pain but of substantial age and/or with multiple risk factors for coronary disease	12	2
Valve Surgery - Before valve surgery or balloon valvotomy in an adult with chest discomfort, ischemia by noninvasive imaging, or both	11	2
Diseases affecting the aorta when knowledge of the presence or extent of coronary artery involvement is necessary for management (eg, aortic dissection or aneurysm with known coronary disease)	9	2
Post Revascularization- Suspected abrupt closure or subacute stent thrombosis after PCI	3	0.58
Primary PCI should be performed in patients with STEMI and cardiogenic shock or acute severe HF, irrespective of time delay from MI onset	3	0.58
SIHD who survived SCD or potentially life-threatening ventricular arrhythmia to assess cardiac risk	2	0.39
After STEMI Persistent instability	1	0.19

Appendix D. Frequency of specific indications for coronary angiography based on ACC/AHA class of recommendation *(continued)*

Indication	N=515	Frequency (%)
Class IIa		
Suspected SIHD whose clinical characteristics and results of non-invasive testing (exclusive of stress testing) indicate high likelihood of severe IHD and who are amenable to and candidates for coronary revascularization	25	5
Primary PCI is reasonable in patients with STEMI if there is clinical and/or ECG evidence of ongoing ischemia between 12 and 24 hours after symptom onset	22	4
Assess risk in SIHD with depressed EF <50% & moderate risk criteria on noninvasive testing with demonstrable ischemia	14	3
UA and NSTEMI Recurrent angina inadequately controlled by medications	12	2
UA and NSTEMI Early invasive strategy (within 12-24 hours) for initially stabilized high-risk patients with UA/ NSTEMI, delayed invasive strategy (25-72 hrs) for for those not at high or intermediate risk	10	2
Suspected symptomatic SIHD who cannot undergo diagnostic stress testing or have indeterminate or nondiagnostic stress tests when there is a high likelihood that the findings will result in important changes to therapy	4	0.78
Unsatisfactory quality of life due to angina, have preserved LV function (EF >50%) and have intermediate-risk criteria on non-invasive testing	4	0.78
Multiple intermediate-clinical-risk markers† and planned vascular surgery	2	0.39
Assess risk in SIHD & inconclusive prognostic information after noninvasive testing or in whom non-invasive testing is contraindicated	1	0.19
Survivors of acute MI with EF <40%, CHF, previous PCI / CABG, malignant ventricular arrhythmia	1	0.19
Post Revascularization/ Post PCI Noninvasive evidence of high-risk criteria detected any time after CABG	1	0.19
High risk for coronary disease when other cardiac surgical procedures are planned (eg, pericardiectomy or removal of chronic pulmonary emboli)	1	0.19
High risk for coronary disease when other cardiac surgical procedures are planned (eg, pericardiectomy or removal of chronic pulmonary emboli)	1	0.19
Before surgery for aortic aneurysm/dissection in patients without known coronary disease	1	0.19
Class IIb		
UA and NSTEMI An ischemia guided strategy may be considered for initially stabilized patients with NSTE-ACS (without serious comorbidities or contraindications to this approach) who have an elevated risk of clinical events	10	2
Suspected persistent occlusion of infarct related artery to perform delayed PCI	5	0.97
CA performed without risk stratification to identify presence of LMCA or 3V-CAD	5	0.97
An ischemia guided strategy in initially stabilized patients (without serious comorbidities or contraindications to this approach) may be reasonable after considering clinician and patient preference	3	0.58
Patients with stress test results of acceptable quality that do not suggest the presence of CAD when clinical suspicion of CAD remains high and there is a high likelihood that the findings will result in important changes to therapy	2	0.39
Asymptomatic post-PCI patient suspected of restenosis within the first months after PCI because of abnormal but not high-risk findings on non-invasive testing	2	0.39

Appendix E. Angiographic results by indication for coronary angiography

Angiogram Findings	CCS n=242	ACS n=222	Valvular n=23	Heart Failure n=14
Normal	37 (15.29%)	17 (7.66%)	**15 (65.22%)**	3 (21.43%)
Non-obstructive CAD	37 (15.29%)	9 (4.05%)	4 (17.39%)	3 (21.43%)
Severe 1-vessel CAD	42 (17.36%)	53 (23.87%)	1 (4.35%)	2 (14.28%)
Severe 2-vessel CAD	42 (17.36%)	47 (21.17%)	1 (4.35%)	1 (7.14%)
Severe 3-vessel CAD	**84 (34.71%)**	**96 (43.24%)**	2 (8.69%)	**5 (35.71%)**
Left Main disease	50 (20.66%)	50 (22.52%)	1 (4.35%)	2 (14.28%)