Appropriate use criteria for coronary angiography: a single centre experience ☆

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ARTICLE INFO

ABSTRACT

Background: Increasing attention is being given to the rational use of invasive procedures. In this study, we aimed to evaluate, among patients referred for coronary angiography, the appropriateness of cardiac catheterization according to the Appropriate Use Criteria (AUC) for diagnostic catheterization and to examine the relationship between the appropriateness and the presence of obstructive coronary artery disease (CAD) and revascularization.
Methods: From November 2017 to December 2018, 1188 consecutive patients referred to undergo a diagnostic catheterization were included. They were categorized as having appropriate, uncertain or inappropriate indication, using a database (Melograno System). We restricted our analysis to 9 appropriate indications including acute coronary syndromes, suspected CAD, valvular heart disease, arrhythmias and cardiomyopathy. We restricted the analysis to the subgroup of patients with suspected or known CAD and, among them, we evaluate the rate of CAD and the need for revascularization.
Results: The indications were appropriate in 1017 patients (85.6%), of uncertain appropriateness in 134 (11.3%), and inappropriate in 37 (3.1%). Restricting the analysis to the CAD subgroup, the indications were appropriate in 848 patients (83.3%), of uncertain appropriateness in 133 (13.1%) and inappropriate in 37 (3.6%). The proportion of patients with critical CAD were 75.9%, 44.3% and 29.7% in the appropriate, uncertain and inappropriate categories respectively (p < 0.001). The revascularization rate was 63.1%, 32.2% and 21.6% in the appropriate, uncertain and inappropriate categories respectively (p < 0.001).
Conclusions: Application of AUC is feasible in a community setting. Melograno system is useful to improve patient care.

1. Introduction

Increasing attention is being given to the rational use of cardiovascular procedures, particularly invasive procedures, in order to reduce procedural risk related to unnecessary tests and improve resources allocation. This is evident in the development and proliferation of Appropriate Use Criteria (AUC) to assess patient selection for coronary procedures [1–5].

Using a method initially developed by the RAND Corporation to address underuse in a rapidly changing health care system, the American College of Cardiology Foundation, the Society for Cardiovascular Angiography and Interventions and several other professional societies established criteria to guide use of cardiovascular procedures, such as diagnostic catheterization and revascularization. The AUC was based, in part, on the results of early studies that identified the relationship between the presence of significant and severe coronary artery disease (CAD) and various demographic and clinical features as well as symptoms [6].

Coronary angiography is defined as appropriate for a specific indication when the expected health benefit (for example, from subsequent revascularization) exceeds the expected negative consequences by a sufficiently wide margin to make it worth doing.

To date, AUC for diagnostic catheterization can affect care delivery in many ways. They should be used to guide physician decision making, reduce inappropriate procedures and help performance evaluation in order to improve healthcare quality. Improving pre-procedural risk stratification and patient selection for coronary angiography may be also one strategy to improve the appropriateness of percutaneous coronary intervention (PCI) [5,7].

☆ These authors take responsibility for all aspects of the reliability and freedom from bias of the data presented and their discussed interpretations.
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According to The American College of Cardiology Foundation and others, the AUC should be incorporated into clinical practice and integrated into electronic health records to examine institutional level of appropriateness and identify areas for improvement [8].

Based on this purpose, an Electronic System called Melograno AUC System is available at Civil Hospital of Ascoli Piceno since November 1, 2017, in order to identify, among patients referred to our center for a diagnostic catheterization, how many of them fulfilled appropriate indications according to the 2012 AUC for diagnostic catheterization [1]. The aim of this study was to evaluate, among patients referred for coronary angiography at our centre, the appropriateness rate according to the AUC. Moreover, to examine the relationship between the appropriateness of coronary angiography and the real presence of obstructive CAD and subsequent revascularization.

2. Methods

This is a monocentric prospective observational registry based on the analysis of data collected in a database called Melograno AUC System, available at our Institution since November 2017. All patients referred for cardiac catheterization at our intervention laboratory from 1 November 2017 to 31 December 2018 were included and categorized as having appropriate, uncertain, or inappropriate indication for diagnostic catheterization according to the AUC. As we applied European Society of Cardiology guidelines, ethical committee approval was not required. All patients signed informed consent to treatment of their personal clinical data. The appropriateness score (scale of 1 to 9), as defined by the 2012 AUC for diagnostic catheterization was categorized as appropriate (7 to 9), uncertain (4 to 6), or inappropriate (1 to 3). Appropriateness was adjudicated on the basis of the data available at the time of referral for coronary angiography using an automated computer algorithm. These were embedded into this algorithm and detailed information on demographic and clinical characteristics, symptom severity, and comorbidity conditions as well as results of preliminary non-invasive cardiac testing were included.

After angiographic evaluation, detailed information on the results of the angiogram as well as need for revascularization were also included to allow subsequent validation and post-hoc analysis.

In the study period, 1188 consecutive patients referred to our cath lab for coronary angiography were considered. We analyzed: baseline demographic characteristics, major cardiovascular risk factors, past cardiovascular history, diagnosis of acceptance, noninvasive functional or anatomical assessment (ergometric test, stress test with imaging such as single-photon emission computed tomography myocardial perfusion imaging (SPECT MPI); stress echocardiography, stress cardiovascular magnetic resonance (CMR), transthoracic echocardiography, computed tomography angiography (CTA) and report of coronary angiography. Patient with multiple studies were categorized according to their first one.

The AUC consist of 102 indications for a spectrum of cardiovascular conditions, including acute coronary syndromes (ACS), valvular heart disease, and arrhythmias [1]. We restricted our analysis to 9 appropriateness indications relevant to patients with ACS, suspected CAD, valvular heart disease, arrhythmias and cardiomyopathy (indications from 1 to 90, and indications 93–95 of the AUC). We did not include patients whose indications for diagnostic catheterization were pericardial diseases (91 and 92) and pulmonary hypertension or intra-cardiac shunt evaluation (from 96 to 102).

Patients were carefully divided into nine groups following the appropriateness indications proposed by the AUC [1]:

- Group 1: Suspected or know ACS: ST-elevation myocardial infarction (STEMI) or suspected STEMI and Unstable Angina/ Non ST-elevation myocardial infarction (NSTEMI)
- Group 2: Suspected CAD (no prior PCI, no prior coronary artery bypass graft (CABG) surgery, or angiogram showing ≥50% angiographic stenosis) without prior noninvasive Testing
- Group 3: Suspected CAD (no prior PCI, CABG, or angiogram showing ≥50% angiographic stenosis) with prior noninvasive Testing
- Group 4: Adjunctive invasive diagnostic testing in patients undergoing diagnostic coronary angiography: fractional flow reserve (FFR) and intravascular ultrasound (IVUS)
- Group 5: Know obstructive CAD (prior myocardial infarction (MI), prior PCI, prior CABG or obstructive CAD on invasive angiography)
- Group 6: Arrhythmias
- Group 7: Preoperative coronary evaluation for non-cardiac surgery in stable patients
- Group 8: Valvular disease
- Group 9: Cardiomyopathies

Among all these groups, we evaluated the appropriateness rate of invasive evaluation.

Moreover, we restricted the analysis to a subgroup of patients with suspected or known CAD (CAD group) including all the patients except patients with valvular disease and cardiomyopathies (group 1 to 7). Among them, we evaluated the real presence of obstructive CAD and the need for subsequent revascularization.

Our primary end-point was to evaluate the appropriateness rate for coronary angiography according to the AUC criteria. The secondary endpoint was the diagnostic yield of the index coronary angiographic study and the subsequent revascularization in the CAD subgroup. Diagnostic yield was based on the presence of critical CAD, defined as native coronary artery stenosis of at least 70% in the left anterior descending, circumflex, or right coronary artery or at least 50% in the left main coronary artery. The need for subsequent revascularization was defined as either PCI or CABG within 30 days from angiography.

2.1. Statistical analysis

Descriptive statistics of data according to appropriateness categories has been performed. Data were reported as mean ± standard deviation for continuous variables, and percentages (absolute numbers), for qualitative variables. Differences in baseline characteristics among appropriateness categories were compared by using the chi-square test for categorical variables and analysis of variance for continuous variables. In our primary analysis we compared the proportion of obstructive CAD among appropriateness categories by using univariate chi-square test.

Multivariate logistic regression was performed to assess the impact of a set of factors on the appropriateness rate according to the AUC (dependent variable). Variables were entered *en bloc* in the multivariate model. Model fit was assessed using the Hosmer-Lemeshow goodness of fit model. Cox and Snell R square and Nagelkerke R square were used to identify the amount of variation in the dependent variable explained by the model. We used SAS version 9.3 for all analysis and considered P values <0.050 to be significant.

3. Results

Baseline demographic characteristics, risk factors, past cardiovascular history of the entire study population are summarized

in Table 1. The average age was 68 ± 12 years and the majority were male (71.2%). Among total population, 18.4% underwent previous coronary revascularization.

Table 2 describes the indications for coronary angiography of the entire study population according to the AUC and the three appropriateness categories. The indications were appropriate in 1017 patients (85.6%), of uncertain appropriateness in 134 (11.3%), and inappropriate in 37 (3.1%).

It was observed that the greatest number of coronary angiographies were performed in patients with ACS (58.4%) followed by patients with suspected CAD with prior non-invasive testing (12.6%) and then by patients with cardiomyopathies (10.5%) (Table 2). The 68.1% of all appropriate coronary angiographies were performed in patients with ACS. The lowest rate of inappropriateness is reached among patients with suspected CAD and no prior noninvasive testing (29.7%) followed by those with known obstructive CAD (27%) and those with suspected CAD with prior non-invasive testing (24.4%).

Table 3 focuses on patients included into the CAD subgroup (group 1 to 7), and shows a similar distribution of baseline characteristics across the appropriateness categories.

Considering only the CAD subgroup (1018 patients), 848 (83.3%) underwent appropriate coronary angiography, 37 (3.6%) received

inappropriate coronary angiography and 133 (13.1%) underwent coronary angiography despite uncertain indications (Table 3).

Further restricting the analysis to patients undergoing coronary angiography for suspected stable ischemic heart disease (indications 5 to 39 of the AUC, group 2 and 3 of our analysis), Table 4 shows the appropriateness ratings. The scenarios for suspected stable ischemic heart disease include patients with prior noninvasive testing and patients without prior noninvasive testing. For patients without prior noninvasive testing with symptoms, the pretest probability (low, intermediate, or high) was used to rate the appropriateness, and for patients without prior non-invasive testing without symptoms, the global CAD risk (low, intermediate, high) was used for AUC ratings. For patients who had prior noninvasive testing, we applied indications 11 to 38 from the AUC. As noted in Table 4, patients who were rated as inappropriate in the suspected stable ischemic heart disease (10.9%) were asymptomatic patients with no prior noninvasive testing and low or intermediate global CAD risk (40%), symptomatic patients and low pretest probability (15%) and patients with prior noninvasive testing with low risk findings/asymptomatic (45%). Patients who were rated as appropriate were symptomatic patients with no prior noninvasive testing and high pretest probability of CAD (18.8%), symptomatic patients with intermediate-risk stress testing (10.1%), patients evaluated with transthoracic echocardiography (7.2%) and coronary CTA (1.5%) and patients with high-risk stress test, regardless of symptoms (62.4%). Of the 183 patients with suspected stable ischemic heart disease, 69 patients (37.7%) were rated as appropriate, 94 (51.4%) were rated as uncertain, 20 (10.9%) were rated as inappropriate (Table 4).

The diagnostic yield of angiography in the CAD subgroup according to appropriateness category is shown in Table 5.

Overall, 70.1% of patients had critical CAD, with 15.9% having significant left main or triple-vessel-disease. Normal coronaries were more likely among inappropriate cases (p < 0.001). The proportion of patients with critical CAD were 75.9%, 44.3% and 29.7% in the appropriate, uncertain and inappropriate categories respectively (p < 0.001). The proportion of patients undergoing revascularization with CABG or PCI were 63.1%, 32.2% and 21.6% in the appropriate, uncertain and inappropriate categories respectively (p < 0.001).

In the subgroup of patients with suspected stable ischemic heart disease (Table 4) the proportion of patients undergoing revascularization were 58%, 25.5% and 20% in the appropriate, uncertain and inappropriate categories respectively.

Table 6 shows independent predictors of appropriateness according to a multivariate logistic regression analysis. The final multivariate model contained 16 variables. The chi-square value for the Hosmer-Lemeshow test was 4.93, with a significant level

Table 1
Baseline characteristics of the study's population.

Characteristics	All Cases (n = 1188)
Age (years – mean ± standard deviation)	68 ± 12
Sex: Female (%)	342 (28.8)
Sex: Male (%)	846 (71.2)
Hypertension history (%)	998 (84.0)
Diabetes mellitus (%)	352 (29.6)
Hypercholesterolemia (%)	902 (75.9)
Tobacco Use: Current (%)	305 (25.7)
Tobacco Use: Past (%)	291 (24.5)
Previous Revascularization (%)	219 (18.4)
Previous PCI (%)	161 (13.6)
Previous CABG (%)	35 (2.9)
Previous PCI and CABG (%)	23 (1.9)
Previous MI (%)	234 (19.7)
CHF (%)	272 (22.9)
Total Cholesterol, mg/dl (mean ± standard deviation)	195.4 ± 51.7
HDL Cholesterol mg/dl (mean ± standard deviation)	40.2 ± 9.9
LDL Cholesterol, mg/dl (mean ± standard deviation)	118.3 ± 29.1
Triglyceride, mg/dl (mean ± standard deviation)	127.5 ± 46.3
Serum Creatinine, mg/dl (mean ± standard deviation)	1.25 ± 1.00

PCI percutaneous coronary intervention; CABG coronary artery bypass grafting; MI myocardial infarction; CHF congestive heart failure; HDL high density lipoprotein; LDL low density lipoprotein.

Table 2
Indications for coronary angiography of the entire study population according to the appropriate use criteria stratified by appropriateness.

Indication	All Cases N = 1188	Appropriate n = 1017 (85.6%)	Uncertain n = 134 (11.3%)	Inappropriate n = 37 (3.1%)	P Value*
STEMI or suspected STEMI (%)	330 (27.8)	330 (32.4)	- (0)	- (0)	<0.0001
Unstable Angina/NSTEMI (%)	363 (30.6)	363 (35.7)	- (0)	- (0)	<0.0001
Suspected CAD: No Prior Noninvasive Testing (%)	33 (2.8)	13 (1.3)	9 (6.7)	11 (29.7)	<0.0001
Suspected CAD: Prior Noninvasive Testing	150 (12.6)	56 (5.5)	85 (63.5)	9 (24.4)	<0.0001
FFR and IVUS (%)	24 (2.0)	18 (1.8)	6 (4.5)	- (0)	0.1348
Known Obstructive CAD (%)	76 (6.4)	47 (4.6)	19 (14.2)	10 (27.0)	<0.0001
Arrhythmias (%)	37 (3.1)	21 (2.1)	13 (9.7)	3 (8.1)	<0.0001
Preoperative Coronary evaluation for Noncardiac Surgery in Stable Patients	5 (0.4)	- (0)	1 (0.7)	4 (10.8)	<0.0001
Valvular Disease (%)	45 (3.8)	44 (4.3)	1 (0.7)	- (0)	0.0177
Cardiomyopathies (%)	125 (10.5)	125 (12.3)	- (0)	- (0)	<0.0001

STEMI ST-elevation myocardial infarction; NSTEMI Non-ST elevation myocardial infarction; CAD coronary artery disease; FFR fractional flow reserve; IVUS intravascular ultrasound.

Table 3

Indications for coronary angiography according to the appropriate use criteria and clinical characteristics of patients with suspected coronary artery disease (CAD subgroup), stratified by appropriateness.

Indications and Characteristics	All Cases N = 1018	Appropriate n = 848 (83.3%)	Uncertain n = 133 (13.1%)	Inappropriate n = 37 (3.6%)	P Value*
STEMI or suspected STEMI %)	330 (32.4)	330 (100)	0 (0%)	0 (0%)	<0.0001
Unstable Angina/NSTEMI (%)	363 (35.7%)	363 (100)	0 (0%)	0 (0%)	<0.0001
Suspected CAD: No Prior Noninvasive Testing (%)	33 (3.2)	13 (39.4)	9 (27.3%)	11 (33.3%)	<0.0001
Suspected CAD: Prior Noninvasive Testing	150 (14.7)	56 (37.3%)	85 (56.7%)	9 (6%)	<0.0001
FFR and IVUS (%)	24 (2.4)	18 (75%)	6 (25%)	0 (0%)	0.2699
Known Obstructive CAD (%)	76 (7.5)	47 (62%)	19 (25%)	10 (13%)	<0.0001
Arrhytmias (%)	37 (3.6)	21 (56.7%)	13 (35.2%)	3 (8.1%)	<0.0001
Preoperative Coronary evaluation for Noncardiac Surgery in Stable Patients (%)	5 (0.5)	0 (0%)	1 (20%)	4 (80%)	<0.0001
Age (years - mean ± standard deviation)	68 ± 12.2	68.4 ± 12.5	65.8 ± 9.3	64.7 ± 10.3	<0.0001
Sex: Female (%)	296 (29.1)	252 (29.7)	33 (24.8)	11 (29.7)	0.3150
Sex: Male (%)	722 (70.9)	596 (70.3)	100 (75.2)	26 (70.3)	0.3150
Hypertension history (%)	873 (85.8)	736 (86.8)	108 (81.2)	29 (87.9)	0.0346
Diabetes mellitus (%)	307 (30.2)	264 (31.1)	35 (26.3)	8 (24.2)	0.1301
Hypercholesterolemia (%)	815 (80.2)	694 (81.8)	93 (69.9)	28 (84.8)	0.0015
Tobacco Use:Current (%)	282 (27.8)	244 (28.8)	27 (20.3)	11 (33.3)	0.0878
Tobacco Use: Past (%)	255 (25.1)	215 (25.4)	33 (24.8)	7 (21.2)	0.6163
Previous Revascularization (%)	215 (21.2)	183 (21.6)	22 (16.5)	10 (30.3)	0.4216
Previous PCI only (%)	160 (15.7)	134 (15.8)	17 (12.7)	9 (27.3)	0.8681
Previous CABG only (%)	33 (3.2)	29 (3.4)	3 (2.3)	1 (3.0)	0.4735
Previous PCI and CABG (%)	22 (2.2)	20 (2.4)	2 (1.5)	- (0)	0.3334
Previous MI (%)	217 (21.3)	186 (21.9)	20 (15.0)	11 (33.3)	0.2825
CHF (%)	169 (16.6)	158 (18.6)	8 (6.0)	3 (9.1)	0.0001
Total Cholesterol mg/dl (mean ± standard deviation)	200.5 ± 51.3	204.8 ± 50.8	173.4 ± 46.3	172.9 ± 48.5	<0.0001
Cholesterol HDL mg/dl (mean ± standard deviation)	39.9 ± 10.2	39.5 ± 10.1	42.2 ± 9.8	44.7 ± 13.1	<0.0001
Cholesterol LDL mg/dl (mean ± standard deviation)	118.8 ± 28.3	118.7 ± 26.8	119.9 ± 36.2	116.6 ± 37.4	<0.0001
Triglyceride mg/dl (mean ± standard deviation)	129.9 ± 46.5	129.8 ± 43.4	132.3 ± 67.5	124.7 ± 41.2	<0.0001
Serum Creatinine mg/dl (mean ± standard deviation)	1.23 ± 0.98	1.26 ± 1.02	1.0 ± 0.3	1.2 ± 1.36	0.0001

STEMI ST-elevation myocardial infarction; NSTEMI Non-ST elevation myocardial infarction; CAD coronary artery disease; FFR fractional flow reserve; IVUS intravascular ultrasound; PCI percutaneous coronary intervention; CABG coronary artery bypass grafting; CHF congestive heart failure; HDL high density lipoprotein; LDL low density lipoprotein.

Table 4

Patients with suspected stable ischemic heart disease and secondary outcomes.

Variable	Appropriate n = 69 (37.7%)	Uncertain n = 94 (51.4%)	Inappropriate n = 20 (10.9%)	P Value*
No Prior Noninvasive Testing n = 33 (%)	13 (18.8)	9 (9.6)	11 (55)	0.8250
- Asymptomatic, n = 10, (%)	- (0)	2 (2.2)	8 (40)	0.0114
- Symptomatic, n = 23, (%)	13 (18.8%)	7 (7.4%)	3 (15)	0.0464
Prior Noninvasive Testing, n = 150, (%)	56 (81.2)	85 (90)	9 (45)	0.8250
- ECG Stress Testing, n = 120, (%)	42 (60.9)	73 (77.7)	5 (25)	0.2974
Low-risk findings (Duke t.s. ≥ 5%) n = 9, (%)	- (0)	4 (4.3)	5 (25)	0.0167
Intermediate-risk findings (Duke t.s. 4 to −10%) n = 69, (%)	- (0)	69 (73.4)	- (0)	<0.0001
High-risk findings (Duke t.s. ≤ -11%) n = 42, (%)	42 (60.9)	- (0)	- (0)	<0.0001
- Stress Test with Imaging (SPECT MPI, Stress Echocardiography, CMR%), n = 20, (%)	8 (11.6)	9 (9.6)	3 (15)	0.8224
Low-risk findings, n = 9, (%)	- (0)	6 (6.4)	3 (15)	0.0167
Intermediate-risk findings, n = 10, (%)	7 (10.1)	3 (3.2)	- (0)	0.0302
High-risk findings, n = 1, (%)	1 (1.5)	- (0)	- (0)	0.1974
- Echocardiography, n = 7, (%)	5 (7.2)	2 (2.1)	- (0)	0.0605
- Coronary CTA, n = 3, (%)	1 (1.5)	1 (1.1)	1 (5)	0.8748
Revascularization, n = 68, (%)	40 (58)	24 (25.5)	4 (20)	<0.0001
PCI, n = 60, (%)	32 (46.4)	24 (25.5)	4 (20)	0.0023
CABG, n = 8, (%)	8 (11.6)	- (0)	- (0)	0.0002

ECG electrocardiogram; Duke t.s. Duke treadmill score; SPECT MPI single-photon emission computed tomography myocardial perfusion imaging; CMR stress cardiovascular magnetic resonance; CTA computed tomography angiography; PCI percutaneous coronary intervention; CABG coronary artery bypass grafting.

of 0.76. The strongest predictor of appropriateness rate according to the AUC was ACS, followed by chronic heart failure and total cholesterol.

4. Discussion

The main findings of our study are the following: 1) Most of the patients referred to our Institution after the introduction of the AUC-based system, had an appropriate indication to cardiac catheterization; 2) Coronary angiography in patients with an appropriate indication was associated with improved diagnostic yield of critical CAD and more subsequent revascularization; 3) Critical CAD was incidentally detected in about one third of patients with inappropriate indication to invasive diagnostic test, and this translate into percutaneous revascularization in the majority of them.

The first relevant finding that we can infer from this registry is that in our centre there is a high rate (85.6%) of appropriateness of

Table 5
Diagnostic yield of angiography in the coronary artery disease subgroup according to appropriateness category.

Variable	All Cases n = 1018	Appropriate n = 848 (83.3%)	Uncertain n = 133 (13.1%)	Inappropriate n = 37 (3.6%)	P Value*
Normal coronaries (%)	137 (13.5)	89 (10.5)	34 (25.5)	14 (37.9)	<0.0001
Not significant coronary disease (%)	167 (16.4)	115 (13.5)	40 (30.1)	12 (32.4)	<0.0001
Critical coronary disease (%)	714 (70.1)	644 (75.9)	59 (44.3)	11 (29.7)	<0.0001
Revascularization (PCI or CABG) (%)	586 (57.6)	535 (63.1)	43 (32.3)	8 (21.6)	<0.0001
Critical coronary disease: PCI (%)	561 (55.1)	515 (60.7)	38 (28.6)	8 (21.6)	<0.0001
Critical coronary disease: CABG (%)	25 (2.4)	20 (2.4)	5 (3.8)	- (0)	0.9961
Critical coronary disease: medical therapy	128 (12.6)	109 (12.9)	16 (7.5)	3 (8.1)	0.5472
Number of diseased vessels (mean ± standard deviation)	1.09 ± 1.02	1.16 ± 0.94	0.66 ± 0.87	0.43 ± 0.80	0.0007
Total 3-vessel and LM disease (%9	162(15.9)	149 (17.6)	11 (8.3)	2 (5.4)	0.0012
3-vessel disease (%)	101 (9.9)	94 (11.1)	6 (4.5)	1 (2.7)	0.0055
LM disease (%)	61 (6.0)	55 (6.5)	5 (3.8)	1 (2.7)	0.3406
Jeopardy score (mean ± standard deviation)	3.8 ± 3.97	4.44 ± 3.93	2.63 ± 3.79	2.16 ± 3.81	0.0023

PCI percutaneous coronary intervention; CABG coronary artery bypass grafting; LM Left Main.

Table 6
Multivariate logistic regression for the appropriateness rate according to the AUC.

Variable	p-value	OR	95% CI
Jeopardy Score	0.883	0.995	0.927–1.067
Male Sex	0.712	0.903	0.525–1.553
Tobacco Use	0.357	0.965	0.634–1.178
Diabetes mellitus	0.960	1.014	0.585–1.757
Hypertension history	0.521	1.223	0.661–2.264
Hypercholesterolemia	0.214	0.704	0.404–1.224
Chronic Obstructive Pulmonary Disease	0.547	1.390	0.475–4.068
Kidney disease	0.902	1.041	0.545–1.990
Congestive Heart failure	0.0001	7.640	3.441–16.961
Past Myocardial infarction	0.821	1.073	0.583–1.975
Serum Creatinine	0.750	0.939	0.639–1.380
Triglyceride	0.304	0.998	0.994–1.002
Total Cholesterol	0.031	1.015	1.001–1.030
HDL	0.011	0.980	0.964–0.995
LDL	0.533	0.992	0.966–1.018
Acute Coronary Syndrome	0.0001	14.900	6.840–32.460
Constant	0.101	3.671	

The model as a whole explained between 21% (Cox and Snell R square) and 41% (Nagelkerke R square) of the variance in the appropriateness rate according to the AUC, and correctly classified 89% of cases.

diagnostic angiography due to high rate of ACS. The proportion of coronary angiography performed in patients with ACS was 58.4%.

We know that the proportion of appropriate angiography in literature is in the range from 49% to 84%, depending on the study location, study population and method of determining the appropriateness category. In the ACRE study, population based, prospective study, 3631 consecutive patients undergoing coronary angiography (no exclusion criteria) at Royal Hospitals Trust, London, UK, were evaluated. The indications for coronary angiography were rated appropriate in 2253 (62%) patients and inappropriate in 166 patients (5%), largely in asymptomatic or atypical chest pain presentations. The remaining 1212 (33%) angiograms were rated uncertain. The ACRE study predated the publication of the 2012 AUC document by eleven years and used a different standard to assess appropriateness [9].

The second important aspect of our analysis consists in the very low rate (3.1%) of inappropriate tests also in case of suspected stable ischemic heart disease (10.9%). This very low rate could be driven by a sort of deterrent effect generated by the presence of the Melograno AUC system. In fact, we hypothesize that the routine use of the AUC Melograno system has improved over time the correct selection of patients referred to our cath lab. According to our experience the AUC system should be part of daily clinical practice in order to guide clinical decision making, to verify the appropriateness rate of a centre and consequently obtain a quality performance measure.

Regarding the data of outcome in our population, coronary angiography that was rated as appropriate was more likely to diagnose obstructive CAD (75.9%). Patients with appropriate indication had more revascularization (63.1%). A substantial proportion of patients with inappropriate (29.7%) or uncertain (44.3%) indications also had important CAD and 21.6% and 32.3% of those in the inappropriate and uncertain categories respectively had subsequent revascularization.

If we consider only the patients with suspected stable ischemic heart disease, we found 37.7% of angiographic studies classified as appropriate, 51.4% classified as uncertain and 10.9% classified as inappropriate. It is notable that 82.2% of all patients with suspected stable CAD had stress test before coronary angiography.

In a previous study of Hannan et al., the application of the AUC for diagnostic catheterization in New York State showed that among 8986 patients investigated for stable ischemic heart disease between 2010 and 2011 in 18 hospitals, 35.3% of angiographic studies were appropriate, 24.9% were inappropriate and 39.8% had uncertain indications. In this study 50.7% of all patients who could be rated had no stress test before coronary angiography and 31.5% of patients with no stress test results were rated as inappropriate [6].

In the study of Mohareb et al. among the final cohort of 48,336 patients with suspected stable ischemic heart disease, 58.2% of angiographic studies were classified as appropriate, 10.8% were classified as inappropriate, and 31% were rated as uncertain with wide variation across the 18 hospitals in Ontario, Canada. In patients with appropriate indications for angiography, 52.9% had obstructive CAD, with 40.0% undergoing revascularization. In those with inappropriate indications, 30.9% had obstructive CAD and 18.9% underwent revascularization; in those with uncertain indications, 36.7% had obstructive CAD and 25.9% had revascularization [10].

In our study in the subgroup of patients with suspected stable ischemic heart disease (Table 4) the proportion of patients undergoing revascularization were 58%, 25.5% and 20% in the appropriate, uncertain and inappropriate categories respectively. So, the data we obtained in this group are consistent with those reported in literature. Regarding the date of revascularization in the inappropriate group we know that coronary angiography in asymptomatic patients may lead to inappropriate PCI due to a diagnostic-therapeutic cascade.

In the study of Bradley, all hospitals with higher rates of asymptomatic patients at angiography had higher median rate of inappropriate PCI. This was attributable to more frequent use of PCI in asymptomatic patients at hospital with higher rates of angiography in asymptomatic patients [7].

However, the purpose of our study was to evaluate the appropriateness of diagnostic catheterization by the use of Melograno AUC System. Accordingly, we cannot speculate about the prognostic clinical impact of PCI in this group of patients. In this context, these data should be considered at the light of the latest studies and guidelines [11–14]. Particularly, considering the group of patients with stable CAD, the ISCHEMIA trial shown that revascularization by PCI did not confer a reduction in a composite endpoint of cardiovascular death, MI, hospitalization for unstable angina, and heart failure or resuscitated cardiac arrest compared with medical therapy [12]. The ORBITA trial, demonstrated that PCI did not increase exercise time more than medical therapy among patients with medically treated angina and significant CAD [12]. Several future larger studies are required to evaluate the appropriateness of PCI by the specific AUC System.

By the way, improving patient selection for coronary procedures may represent one strategy to improve the appropriateness of PCI. Increased use of invasive functional testing could also limit the rate of inappropriate revascularization.

4.1. Limitations of study

The present paper has some limitations, due to the small sample size and the single-centre study design. Moreover, to evaluate if the Melograno System has really increased the appropriateness of patients referred to our cath lab, it could be useful to analyze patients referred to our cath lab in a previous period, before the introduction of the system itself. Finally, Melograno AUC System does not allow us to extrapolate date about the appropriateness of PCI. Future dedicated larger studies are required to investigate these both points.

5. Conclusion

Our study demonstrates that Clinical application of AUC is highly feasible in a community setting. Although inpatient referral for coronary angiography was appropriate in most patients, strategies aimed at implementing these criteria in clinical practice are desirable. Melograno AUC system is a useful instrument to guide physician decision making, to improve patient care and verify institutional level appropriateness.

Declaration of Competing Interest

The authors do not have conflict of interest.

Acknowledgements

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