Imaging for Chest Pain Assessment: An Algorithmic Approach Using Non-invasive Modalities to Define Medical vs. Interventional Treatment

Taylor Graber MSIV¹, Robert Hamburg MD^{1,2},
Eric vanSonnenberg MD^{1,3}, Paul Kang¹

1. University of Arizona College of Medicine Phoenix, Phoenix, Arizona, USA.
2. Central Arizona Heart Specialists, Chandler, Arizona, USA.
3. David Geffen School of Medicine at University of California Los Angeles, Los Angeles, California, USA.

Abstract

- Background:** Analyze the roles of CCTA, MPI, and CC to formulate a sequential clinical algorithm to use in patients with chest pain, risk factors for CAD, and an abnormal EKG. The goals of the study are to streamline and refine workup, to decrease radiation exposure to patients, and to contain costs.
- Materials and Methods:** 39 patients underwent CCTA, MPI, and CC within 30 months of each other. CCTA was defined by mild, moderate, or severe CAD. MPI used SSS, SDS, TID, and formal reading to define mild, moderate, or severe physiologic ischemia. CC and coronary intervention cine films were analyzed to define and treat anatomical CAD medically or by intervention.
- Results:** There was strong correlation between CCTA, CC, and treatment type ($p < 0.0001$). CCTA was able to stratify all patients with mild or severe ischemia to appropriate treatment groups, and to reduce the need for MPI. With moderate ischemia from CCTA, the additional use of MPI could have reduced the need for 16/18 (89%) patients who underwent CC to undergo further testing. No patients with mild or moderate CAD by CCTA, followed by mild to moderate physiologic ischemia by MPI, needed CC or intervention. 37/39 patients (95%) could have avoided one or more tests using our algorithm.
- Conclusion:** CCTA followed by MPI may be used in symptomatic patients with risk factors for CAD and an abnormal EKG to stratify mild and moderate CAD, and to thereby avoid cardiac catheterization. Our algorithm could lead to savings in healthcare expenditures, save patients from unnecessary invasive procedures, decrease radiation exposure, and reduce total cost.

Introduction

- Cardiac Catheterization (CC) is the gold standard to determine stenosis in symptomatic patients with typical angina.¹ However, it is an invasive test that increases health expenditures and complications, in contrast to less invasive testing.²
- Less invasive testing for typical angina exists in the form of stress EKG, single photon emission computerized tomography myocardial perfusion imaging (SPECT MPI), and cardiac computerized tomography angiography (CCTA).
- CCTA is an advance in cardiac imaging, capable of noninvasively characterizing patency and compromise of the coronary arteries.
- SPECT MPI is another well-established method to determine levels of functional ischemia and physiologic perfusion defects.
- Less invasive, less expensive imaging modalities would be preferable to CC as first line diagnostic maneuvers
- We sought to demonstrate the interrelationship between these three studies (CC, CCTA, MPI) and their ability to determine the appropriate treatment (medical therapy vs. revascularization), by clarifying clear indications for their sequential use.
- To develop a streamlined approach and algorithm for cardiac imaging and risk assessment in symptomatic patients with stable angina and an abnormal EKG.

Methods

Study Population

- We retrospectively screened the database of patients at Central Arizona Heart Specialists, Chandler, AZ to identify those who received MPI, CCTA, and CC from February 2009–June 2014 within a 30 month period.
- The study population includes patients who underwent all three imaging studies within the aforementioned time period, with the MPI exam less than 30 months before CC.
- In total, 56 patients were identified who met the initial criteria.
 - 12 patients were excluded due to the MPI taking place after CC intervention, 3 were excluded due to the MPI taking place >30 months before CC, and 2 were excluded due to a congenital anomaly being the reason for imaging. 3 patients who had MPI after CC were included in the study since no intervention was performed.
- All patients who underwent revascularization were subsequently medically managed according to national guidelines.³ Table 1 further describes patient demographics.

Statistical Analysis

Patient demographic characteristics were ascertained using means and standard deviations for continuous variables; frequencies and proportions for categorical variables. Furthermore, frequencies and proportions were ascertained for each of the assigned categorical grades for the three different tests (MPI, CCTA, CC). The Kruskal-Wallis test was used to determine the ability of each test to predict the level of therapy (medical vs. interventional). Spearman's rank correlation was used to determine the association between any pair of MPI, CCTA, and CC. Unless stated otherwise, p-values < .05 are deemed significant. The Stata software package was used for both graphs and analysis (StataCorp 2013. Stata Statistical Software: Release 13. College Station TX: StataCorp LP).

Results

- 39 patients were included in the current analysis. 19 patients received medical therapy, while 7 patients and 13 patients received CABG and Angioplasty respectively (Table 1). 11 patients (57.9%) and 5 patients (26.3%) within the medical therapy treatment group presented with moderate to severe ischemia after undergoing the MPI SSS and MPI SDS imaging modalities respectively. The CCTA and CC imaging modalities rendered 16 (84.2%) patients and 9 (47.4%) patients with moderate stenosis respectively (Table 1).
- Among the 7 patients within the CABG treatment group, the MPI SSS showed 4 (57.1%) patients with moderate to severe ischemia, while the MPI SDS showed 2 (28.6%) patients with moderate to severe ischemia. All 7 patients within this treatment group showed severe stenosis after undergoing the CCTA and CC imaging modalities.
- The MPI SSS and SDS showed that 6 (46.2%) patients presented with moderate to severe ischemia thus receiving angioplasty. 11 (84.6%) patients and 13 (100%) patients within the angioplasty treatment group showed severe stenosis with the CCTA and CC imaging modalities respectively.
- Of the four imaging modalities, CCTA and CC were correlated to the treatment distributions among the patients ($p < 0.001$ for both).
- Figures 2-3 showed correlations between imaging modalities by assessing the distribution of treatment modalities across specified categories.
- 18/18 patients (100%) with severe stenosis from CCTA were treated with interventional therapy. When CCTA showed mild stenosis (<50%), 3/3 (100%) patients were treated with medical therapy, and none needed interventional therapy (as defined by Hulten et al.¹⁹) regardless of the result from MPI. With moderate stenosis and an MPI SDS score of < 4.0, 12/12 patients (100%) were treated with medical therapy. With an SDS score of > 4.0, 4/6 patients (67%) were treated with medical therapy and 2/6 patients (33%) were treated with interventional therapy (Figure 2).
- Figure 3 shows that with severe stenosis on CCTA, all 18/18 patients had severe stenosis on CC, and all underwent interventional therapy. With mild stenosis on CCTA, 3/3 patients had mild stenosis on CC and all had medical therapy. With moderate stenosis from CCTA, 5/18 (28%) patients had mild stenosis on CC and underwent medical therapy; 9/18 (50%) patients had moderate stenosis on CC and underwent medical therapy; 4/18 patients (22%) had severe stenosis on CC with 2 receiving medical therapy and 2 interventional treatment.
- Figure 4 shows that using MPI by SDS as a first line diagnostic test with CCTA as a follow-up did not effectively stratify patients into categories that are predictive of treatment type.

Figure 2 Depicts type of therapy related to stenosis on CCTA and ischemia on MPI SDS:

*Histogram showing the correlation between CT coronary angiography (CCTA – major grouping on x-axis) vs. myocardial perfusion imaging (MPI) by summed difference score (SDS) (subgrouping on x-axis) with the corresponding type of prescribed medical treatment (medical therapy, surgical intervention, stenting) in color coding.

Figure 3 illustrates the interrelationship between severity of stenosis on CC and CCTA correlating to therapy type.

*Histogram showing the correlation between CT coronary angiography (CCTA – major grouping on x-axis) vs. cardiac catheterization (CC – subgrouping on x-axis) with the corresponding type of prescribed medical treatment (medical therapy, surgical intervention, stenting) in color coding.

Figure 4 shows that using MPI SDS as a first-line imaging test did not place patients in predictive categories that could be used to predict treatment modality.

*Histogram showing the correlation between myocardial perfusion imaging (MPI) by summed difference score (SDS) (major grouping on x-axis) vs. cardiac catheterization (CC – subgrouping on x-axis) with the corresponding type of prescribed medical treatment (medical therapy, surgical intervention, stenting) in color coding.

Discussion and Conclusions

Using our algorithm (Figure 5), 3/39 patients (8%) could have avoided testing with MPI and CC, 21/39 patients (54%) could have avoided MPI, and 16/39 patients (41%) could have avoided CC, with only 2/39 patients (5%) needing all three imaging studies. Thus, in our cohort, **37/39 patients (95%) could have avoided one or more tests.**

This retrospective study has helped establish the relative importance and interrelationships of CCTA, MPI, and CC. CCTA is a noninvasive imaging approach to determine CAD with high levels of sensitivity, specificity, and negative predictive value. Its use as a first line imaging modality in the patient with stable angina and an abnormal EKG is suggested by our study. Following a result from CCTA showing moderate stenosis (50-70%), MPI yields prognostic benefit to determine therapy stratification. The utilization of these imaging studies according to our algorithm should reduce the need for invasive CC, using it only for confirmatory diagnosis and eventual treatment in the setting of severe stenosis, while simultaneously avoiding the unnecessary use of MPI (such as using MPI when CCTA shows mild or severe stenosis). Future prospective analysis using our algorithm is warranted, assessing outcomes at each level of the algorithm, to measure the development of adverse coronary events and the response to the different therapies that were guided by the proposed algorithmic approach.

Figure 5 Proposed imaging algorithm explaining when to use CCTA, MPI, and CC.

*Revascularization in Figure 5 includes angioplasty, stents, CABG

Acknowledgements

We acknowledge the Dignity Health Hospital Network and Central Arizona Heart Specialists who have helped carry out this study, including Aubree A Isenhardt MSIII, Denise M Buque CCMA, and Michael T Campbell.

Table 1: Patient Data

Variable	Medical Therapy N = 19	CABG N = 7	Angioplasty N = 13	P-Value*	Spearman's Rho (P-Value)
Age at First Test (years, SD)	72.7 (9.5)	74.4 (7.2)	68.9 (9.5)	0.34	-0.19 (0.25)
Time Between Test (years, SD)	6.65 (0.96)	6.27 (0.81)	1.8 (0.82)	0.23	0.08 (0.42)
Gender (Male, %)	8 (42.1)	6 (85.7)	10 (76.9)	0.06	-0.34 (0.02)
MPI SSS Results (n, %)					-0.16 (0.52)
Normal	2 (10.5)	3 (42.9)	4 (30.8)		
Mild	9 (47.4)	0 (0)	7 (53.8)		
Moderate to Severe	11 (57.6)	4 (57.1)	6 (46.2)	0.54	0.13 (0.35)
MPI SDS Results (n, %)					
No Ischemia	10 (52.6)	4 (57.1)	3 (23.1)		
Mild Ischemia	4 (21.1)	1 (14.3)	2 (15.4)		
Moderate to Severe	5 (26.3)	2 (28.6)	6 (46.2)		
CCTA Results (n, %)				<0.001	0.80 (<0.001)
Mild	3 (15.8)	0 (0)	0 (0)		
Moderate	10 (52.6)	0 (0)	2 (15.4)		
Severe	6 (31.6)	7 (100)	11 (84.6)		
CC Results (n, %)				<0.001	0.82 (<0.001)
Mild	8 (42.1)	0 (0)	0 (0)		
Moderate	9 (47.4)	0 (0)	0 (0)		
Severe	2 (10.5)	7 (100)	13 (100)		

*P-Value Calculated Using Kruskal-Wallis Test for ordinal variables and Fisher's Exact for nominal variables.