Characteristics of STEMI Patients Who Do Not Undergo Percutaneous Coronary Intervention After Prehospital Cath Lab Activation.

Short Title: No PCI after Prehospital STEMI Cath Lab Activation

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Paul Musey, MD has no conflicts of interest to disclose.

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Abstract

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Objectives: To assess the clinical and electrocardiographic characteristics of patients diagnosed with ST elevation myocardial infarction (STEMI) that are associated with an increased likelihood of *not* undergoing percutaneous coronary intervention (PCI) after prehospital coronary catherization lab activation (CCL) in a regional STEMI system.

Methods: We performed a retrospective analysis of prehospital CCL activations in Mecklenburg County, North Carolina between May 2008 and March 2011. Data were extracted from the prehospital patient record, the prehospital ECG, and the regional STEMI database. The independent variables of interest included objective patient characteristics as well as documented cardiac history and risk factors. Analysis was performed using descriptive statistics and logistic regression**.**

Results: 231 prehospital activations were included in the analysis. Five independent variables were found to be associated with a increased likelihood of *not* undergoing PCI: increasing age, bundle branch block (BBB), elevated HR, left ventricular hypertrophy (LVH), and non-white race. The variables with the most significance were any type of BBB (AOR 5.66; 95% CI 1.91 to 16.76), LVH (AOR 4.63; 95% CI 2.03 to 10.53), and non-white race (AOR 3.53; 95% CI 1.76 to 7.08). Conversely, the only variable associated with a higher likelihood of undergoing PCI was the presence of arm pain (AOR 2.94; 95% CI 1.36 - 6.25).

Conclusions: Several of the above variables are expected ECG mimics, however the decreased rate of PCI in non-white patients highlights an area for investigation and process improvement. This may guide the development of prehospital STEMI protocols while avoiding false positive and inappropriate activations.

Introduction

Coronary artery disease and its sequelae, specifically acute myocardial infarction (AMI), is an epidemic. Every thirty-four seconds an American will have an AMI, making coronary heart disease the single largest killer of Americans.(1) We have known for years that early reperfusion of patients with acute myocardial infarction (AMI) can have a significant impact on morbidity and mortality and that the benefits of treatment decline quickly if not instituted early. (2, 3) Patients with ST elevation myocardial infarction (STEMI) in particular benefit from rapid reperfusion therapies such as percutaneous coronary intervention (PCI) and fibrinolytics. (2, 4-6) However, each thirty minute delay to reperfusion increases the relative risk of one year mortality by 7.5%. (6)

Thus, increasing emphasis is being placed on methods to improve the quality of STEMI care by decreasing the total time from onset of symptoms to definitive treatment. These goals are reflected in the 2013 American College of Cardiology Foundation / American Heart Association (ACCF/AHA) guidelines, which recommend that patients identified with STEMI receive reperfusion therapy, preferably PCI within ninety minutes of first medical contact. Prehospital identification and cardiac catheterization lab (CCL) activation for STEMI patients are class 1 recommendations of the ACCF/AHA.(7)

The ECG is an integral part of prehospital chest pain evaluation. When these ECGs are obtained in less than nine minutes by prehospital personnel, there is a significant association with achieving PCI within ninety minutes.(8) Thus across the US, efforts are being made to develop regional STEMI systems of care incorporating prehospital ECGs. This allows for more efficient transport of patients to centers with appropriate reperfusion capabilities, resulting in improved outcomes.(9-14) However,

while studies have shown that trained paramedics are able to identify STEMIs on prehospital ECGs, they do have difficulty with ECG STEMI mimics. (15-17)

In this study, we evaluate a regional system in North Carolina that has, since its inception, improved time from first medical contact to cardiac catheterization in patients diagnosed with a STEMI in the prehospital setting. In this process improvement and hypothesis generating study, we hypothesized that there would be several patient characteristics and prehospital ECG features that may allow for the differentiation of patients who do not undergo PCI after protocol driven prehospital CCL activation.

Methods

Study Design and Setting

This was a retrospective analysis of all patients diagnosed with a STEMI via a prehospital ECG and transported by EMS to any of the three PCI centers in Mecklenburg County, North Carolina. This investigation was performed with local IRB approval. Each of the three included PCI capable STEMI receiving hospitals have been accredited by the Society of Cardiovascular Patient Care.(18) These centers are also a part of the Reperfusion of Acute Myocardial Infarctions in Carolina Emergency Departments (RACE), which is North Carolina's statewide STEMI system.(11) The EMS agency, "Medic," is a public utility controlled by Mecklenburg County along with the two major local healthcare systems in the area, Carolinas Medical Center and Novant Presbyterian Hospital. Mecklenburg County includes the city of Charlotte and has a population of approximately 919,000. At the time of this analysis, Medic was a single-tier, all advanced life support service. All first responders are BLS trained with AED capabilities.(8) During the study period paramedics received standardized didactic

training regarding the STEMI protocol and 12 lead ECG interpretation at least annually and participated in one simulated STEMI patient encounter in the Agency's simulation center.

Study Population

Medic has maintained a registry of all prehospital STEMI activations since May 2007. The patient population included all "scene call" transported STEMI patients in Mecklenburg County, North Carolina from May 2008 and March 2011. All study patients met the current "Code STEMI" protocol guidelines established for prehospital coronary catheterization lab (CCL) activation. "Code STEMI" refers to a protocol launched in May 2007 by Medic and the three PCI hospitals in this study. The protocol requires that the patient be over the age of eighteen, have chest pain or chest pain equivalent symptoms, and have ECG findings consistent with an acute STEMI. This protocol allows prehospital providers to bypass hospitals not capable of PCI, bringing patients meeting "Code STEMI" criteria directly to an activated CCL at a PCI institution.

Activation of "Code STEMI" in the field requires the prehospital 12-lead ECG to have both a computer algorithm interpretation of "Acute STEMI" and a Medic visual confirmation of at least >1-mm ST-segment elevation in two or more contiguous limb leads or contiguous precordial leads. These prehospital ECGs were obtained using the Phillips MRX Monitor/Defibrillator and proprietary algorithm. After these criteria have been met, the ECG is transmitted and reviewed by the emergency physician (EP) at the destination PCI center, and the history is confirmed by radio. If the EP agrees then he/she activates the CCL with one phone call to a central operator, who then contacts the cardiology interventionalist and staff. The CCL has in-hospital staff weekdays

between 7am-6pm. Outside of these times, on call personnel are required to be in the CCL within thirty minutes of an activation.

Study Protocol and Outcome Measures

All patients that were classified as "Code STEMI" and who were transported from a scene call were included for review. These patients were taken directly to the cath lab bypassing the ED except during "on call hours" where the patient would be brought to the ED for a brief period of time awaiting cath lab staff arrival. This purpose of this study was to evaluate prehospital CCL activation, thus, "Code STEMI" patients not identified in the field, i.e. transferred from another hospital or activated within the ED were excluded. The data were extracted from the prehospital patient record, the prehospital ECG, and the regional STEMI database. Activated patients who arrived in the CCL were identified based on the presence of a documented "cath lab ready time." The **primary outcome of interest** was the occurance of PCI. Patients undergoing PCI were identified based on the presence of a documented "lesion treatment time." Those without a documented lesion treatment time were classified as not undergoing PCI. The independent variables of interest included objective patient characteristics (age, sex, race, BP, HR, O2 sat, etc) as well as documented cardiac history and other risk factors (prior MI, HTN, heart failure, peripheral vascular disease, angina, diabetes, tobacco use). ECGs were analyzed for bundle branch block (BBB), left ventricular hyperterophy (LVH), QRS duration, etc. Cases with incomplete records (missing prehospital report or missing associated ECG) were excluded from analysis.

Data Analysis

Preliminary data analysis was conducted using descriptive statistics and univariate odds ratios (OR). Descriptive analyses were performed to investigate potential associations between independent variables and the primary outcome of PCI. Chi-squared analysis and Student's t-test were used to determine initial significance where appropriate. Univariate ORs were calculated for each independent variable to assess its magnitude of effect on the outcome.

In order to further explore the relationships among independent variables and the outcome variable, unconditional multivariable logistic regression was performed. Model building began with all variables demonstrating statistical significance univariately loaded into the model. An investigator-driven stepwise backward selection approach was then undertaken wherein independent variables were removed from the model one at a time in order to achieve parsimony. At each step all remaining variables were assessed and the variable with the highest Wald p-value was removed from the model. This process was repeated until all variables in the model retained statistical significance at the α =0.05 level.

Confounding was assessed by observing the effects of initially insignificant independent variables on the remaining significant variables. A change in the odds ratio of 10% in any variable was considered sufficient evidence to conclude confounding and the variable, regardless of its statistical significance, would remain in the model. Upon completion of the main effects model, plausible interaction terms were created and effect modification was assessed. Only those interaction terms with a Wald p-value ≤ 0.01 were added to the model. Model fit and discrimination was assessed using the Hosmer-Lemeshow goodness of fit test. All data were abstracted from patient records

and entered into Microsoft Excel (Redmond, WA). All statistical analyses were conducted using Stata v.10 (College Station, TX).

Results

Characteristics of study subjects:

There were 341 prehospital Code STEMI activations in Mecklenburg County, NC available for analysis between May 2008 and March 2011. 315/341 (92%) had complete records and were initially included for analysis. Of these complete records, 84/315 (27%) were found to have a protocol violation verified by secondary review of the Medic record and ECG. Of these, only 5 patients had a cath lab ready time but 0 underwent PCI per record review. (Fig 1) The breakdown of protocol violations are as follows: Positive symptoms/negative ECG = 45/84 (54%); Negative symptoms/negative ECG = 12/84 (14%); Negative symptoms/positive ECG = 27/84 (32%). (Fig 2) Thus, these 84 patients were excluded from primary analysis as they were protocol deviations and had no clear indication for catheterization.

There were 231 complete records without a protocol violation that were ultimately analyzed. 150/231 (65%) of these patients went to the CCL as evidenced by a documented "cath lab ready time" and 122/231 (53%) underwent PCI (documented lesion treatment time). Males made up a large proportion of the patients analyzed with 163 (71%) males compared with 68 (29%) females. 140 (61%) were white compared with 91 (39%) patients with a race other than white. The mean age of patients included was 60.7 years (95% CI 58.9 to 62.5) while the mean HR was found to be 91.7 bpm

(95% CI 87.4 to 96.1). Arm pain was documented as being present in 67 (29%) of the patients at the time of medic evaluation. (Table 1)

Comorbid factors analyzed included diabetes, hypertension, COPD, asthma and cancer. 51 (22%) patients had diabetes and 146 (64%) had hypertension. COPD was a documented comorbidity in 12 (5%) patients while 11 (5%) patients had asthma. 18 (8%) patients had a documented form of cancer. Upon evaluation of the ECGs, LVH was present in 51 (22%) patients and 31 (13%) had a bundle branch block. Mean QRS duration was found to be 104.5 (95% CI 100.7 to 108.1). (Table 1).

Main results:

The main outcome variable of interest in this analysis was whether a patient underwent PCI, as by the presence of a documented lesion treatment time regardless of whether they went to the cath lab. 109 (47%) patients did not have a documented "lesion treatment time", indicating that no PCI took place. Of note, there were not any patients who did not have a documented "cath lab ready time" who went on to have PCI. Through logistic regression and descriptive analysis there were 5 independent variables found to be associated with an increased likelihood of *not* undergoing PCI while there was one variable found to be associated with a higher likelihood of undergoing PCI . This model demonstrated good fit with a Hosmer-Lemeshow goodness of fit test of p=0.21. There were no residual confounding variables identified nor were there any interaction terms identified as significant. Odds Ratios (OR) and Adjusted Odds Ratios (AOR) for the variables included for analysis appear in Table 2.

Those patients with any type of BBB were significantly more likely to not have PCI after being declared a STEMI by medics with an AOR of 5.66; (95% CI 1.91 –

16.76) when compared to patients without BBB. Patients with LVH were significantly more likely to not have a PCI with an AOR of 4.63; (95% CI 2.03 – 10.53). In addition, any race other than white was found to be associated with an increased likelihood of not undergoing PCI (OR 3.53; 95% CI 1.76 to 7.08). For every 10 year increase in age the likelihood of not having PCI increased by 1.42 (95% CI 1.11 to 1.81). For every 10 beat increase in HR, the likelihood of not undergoing PCI increased by 1.21 (1.08 to 1.36). The one variable associated with a significantly higher likelihood of undergoing PCI was the presence of arm pain (odds ratio of 2.94 (95% CI 1.36 - 6.25). (Table 2)

Discussion

Prehospital single call CCL activation for patients with STEMI by medics or EPs are at the heart of the effort to comply with the ACCF/AHA guidelines. In the system described here, EPs place one call 24/7 to a central operator, who then activates both the cardiology interventionalist and the CCL staff to prepare for reperfusion while the patient may still be en route to the hospital. (11), (19, 20) This is especially important during off-peak times when cardiology staff may not be in-house. These calls are increasingly being based on the prehospital ECGs as described above. When done correctly, this method has been shown to significantly reduce door to balloon (D2B) time. However, this push for speed may result in decreased specificity of STEMI system activations, and an increase in the rate of false positive or inappropriate CCL activations. The rate of inappropriate or false positive activations range between 5 to 24% depending on the particular system in place for CCL activation (prehospital vs ED physician) in the published literature across the country. (20),(21-23) In an era when

healthcare costs are scrutinized carefully, the monetary and human cost associated with an inappropriate CCL activation is not insignificant.

In our study population, the rate of inappropriate or false positive activations (protocol violations) by prehospital personnel was 27% (84/315). (Fig 1 and Fig 2) These patients were inappropriately identified as having a STEMI in the prehospital environment and the CCL should not have been activated. Additionally, the proportion of patients without a protocol violation actually receiving a reperfusion intervention in this study was 53% (122/231). However, as reported by Garvey et al, when evaluating the state-wide NC system as a whole, combining activations by both emergency physicians and EMS personnel between 2008 and 2009, the rate of inappropriate activations was lower at 15%. The rate of patients undergoing PCI system-wide was also noted to be higher at 77%.(24) Recent studies have shown that trained paramedics are quite proficient in identifying inferior STEMIs but can be confounded by mimics or STEMIs in other distributions. (17, 25) This is an opportunity to reevaluate and focus our paramedic ECG interpretation training and protocols.

Interestingly, our results also showed that non-white patients had an increased likelihood of *not* undergoing PCI. This highlights possible racial disparities when it comes to MI management. It is well documented that non-whites have a significantly higher mortality rate and worse clinical outcomes when compared to white patients having an AMI. (26) In addition, non-whites are less likely to receive reperfusion therapy or be transferred for PCI. (27-29) Many explanations have been suggested as to the cause of this disparity including worse CAD, abundant co-morbidities, worse socioeconomic status, and geographic location with impaired access to specialists.

These all may play a role in addition to a delayed presentation, slower triage and possible provider biases. (27, 30) However, it is difficult to ascertain the predominant factors associated this disparity especially with a protocol that should treat all-comers equally. With the data available it is unclear if some of these patients that did not undergo PCI went on to get bypass grafting due to more advanced CAD or not. However, there is significant room for improvement as studies have shown that STEMI patients who are eligible, regardless of race, receive PCI they have similar clinical outcomes. (27, 31) This result in particular would benefit from a larger prospective cohort analysis looking at MI management within the system to identify the leading causes of this disparity including any provider biases (unconscious or otherwise).

With regard to age, we found that, in general, patients of increasing age were less likely to receive PCI. This is not surprising as elderly patients, especially over the age of 75, are less likely to receive reperfusion therapy.(32, 33) Increasing age has been shown to be an independent negative predictor for revascularization despite the fact that elderly patients with STEMI have worse outcomes than younger patients. (29, 34) In our study 85/231 patients were found to be over the age of 65. Interestingly, there was not a distinct steep drop in PCI at age 65 or greater. Rather, the results were linear: for every 10 year increase in age, the likelihood of *not* receiving PCI increased by 1.42.

The reasons for this are complex. Delayed presentations, a large amount of co-morbidities, and lack of clinical data have been posited as reasons for decreased reperfusion interventions in elderly patients. (32) These patients have generally been a small minority, or excluded all together from STEMI study populations. The few studies that have been done point to a decreased success rate of PCI in the elderly compared

with younger counterparts. (35, 36) If we want to improve the quality of care in the elderly, effort must be taken to include patients with STEMI older than 65 in large randomized trials.

The presence of pain radiating to the arm was the only variable found to be independently associated with a significantly increased likelihood of undergoing PCI confirming what we have seen in the vast majority of data and teaching about AMI thus far. As such, both the AHA and European Society of Cardiology (ESC) guidelines report radiation of pain to the arm as highly likely to be related to ACS. (37) Thus it should be assessed in any patient suspected of having an AMI. Radiation of pain to the right upper extremity has been shown to be even more associated with AMI than pain radiating to the left upper extremity. However, pain radiating to both arms has the strongest association and is more predictive of AMI. (37-39) Our records did not distinguish between right, left, or both. Only the presence of arm pain or lack thereof was documented. Nonetheless, the presence of arm pain significantly increased the chances of the patients in this study undergoing PCI.

Our data showing the presence of ECG LVH or BBB being significantly associated with a increased likelihood of not undergoing PCI is also not surprising. These variables had the strongest associations with AORs of 4.63 and 5.66 respectively. LVH and LBBB are well known as conditions that may confound ECG STEMI identification. Additionally, patients with RBBB often have ST segment changes especially in the anterior leads that can also make STEMI identification difficult. (22),(40, 41) In fact, the number of patients with non-infarctional ST elevation related to LVH or LBBB have been noted in several studies to be far in excess of those with ST

elevation associated with AMI. (42) Because the repolarization abnormality associated with LVH can be mistaken for ischemia, it has been reported as the most significant predictor of false positive STEMIs and CCL activations. (21, 43, 44) While new or presumed new LBBB has been considered a STEMI equivalent, it is often difficult to determine if these changes are new in the prehospital setting. Thus, while current guidelines from the ACCF/AHA as well as the ESC advocate for the early use of PCI with new or presumed new LBBB, they note that LBBB "should not be considered diagnositic of an MI in isolation."(7)

Limitations

Weaknesses associated with this study include the fact that this was a retrospective prehospital chart and database review. Inherently these studies are at the mercy of presumed correct prehospital documentation and data abstraction. It is possible that some of our patients had certain characteristics that we analyzed but were either not self-reported or documented and thus not included. We did not have access to the patient's in-hospital charts including cath lab reports except the documentation of a "cath lab ready" time and a "lesion treatment" time that are regularly collected per registry protocol. As such we also do not have documentation as to the reason why an individual either did not go to the lab or did not receive an intervention. More importantly, we do not know the disposition of these patients beyond whether or not they had an actual intervention (PCI). Some patients not undergoing PCI may have had some other treatment such as bypass grafting. We also cannot assess how many patients expired before receiving an intervention or declined an intervention all together.

Conclusion

In summary, this study adds to our knowledge of prehospital STEMI management. Several systems have proposed an acceptable miss rate for CCL activation of 5-10% for STEMI.(20, 45) This leaves a significant amount of room for improvement, especially in the prehospital environment. While our regional system is aggressively working to optimize the time from first medical contact to reperfusion, we now have the opportunity to develop system-wide mechanisms to increase prehospital activation efficiency.(8) We know there are a subset of STEMI activations from the prehospital setting that are less likely to undergo PCI. The results of our study may be useful in developing or revising protocols with specific patient characteristics to increase the specificity of prehospital STEMI system activation. Future studies may benefit from a larger sample of patients to assess potentially interesting interaction terms that this study was underpowered to assess. This work would also benefit from prospective evaluation of CCL activation from the prehospital setting and see if these variables associated with an increased likelihood of *not* undergoing PCI, especially non-white race, continue to show significance.

Fig 1. : Results Flowchart – PCI vs. No PCI


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                    ┌─────────────────┐
                    │   Prehospital   │
                    │     STEMI       │
                    │   Activations   │
                    │      341        │
                    └─────────────────┘
                   /                   \
      ┌──────────────┐              ┌──────────────┐
      │  Excluded:   │              │   Complete   │
      │  Incomplete  │              │   Records    │
      │   Records    │              │     315      │
      │     26       │              └──────────────┘
      └──────────────┘
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Prehospital STEMI Activations 341

Excluded: Incomplete Records 26

Complete Records 315

Excluded: Protocol Violations 84

Included: No Violations 231 (100%)

Cath Lab Ready Time 5

Cath Lab Ready Time 150 (65%)

NO Cath Lab Ready Time 81 (35%)

Underwent PCI 0

Underwent PCI **(Documented lesion treatment time)** 122 (53%)

No PCI 109 (47%)

Breakdown of primary outcome (PCI vs. No PCI). Documented Lesion treament time = PCI. Percentages shown refer to patients included for analysis only.

Fig 2. Protocol Violation Breakdown

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                    ┌─────────────────────┐
                    │  Protocol Violations │
                    │       (n=84)         │
                    └─────────────────────┘
                               │
         ┌─────────────────────┼─────────────────────┐
┌──────────────────┐  ┌──────────────────┐  ┌──────────────────┐
│     Positive      │  │     Negative      │  │     Negative      │
│ Symptoms/Negative │  │ Symptoms/Negative │  │ Symptoms/Positive │
│       ECG         │  │       ECG         │  │       ECG         │
│                   │  │                   │  │                   │
│     45 (54%)      │  │     12 (14%)      │  │     27 (32%)      │
└──────────────────┘  └──────────────────┘  └──────────────────┘
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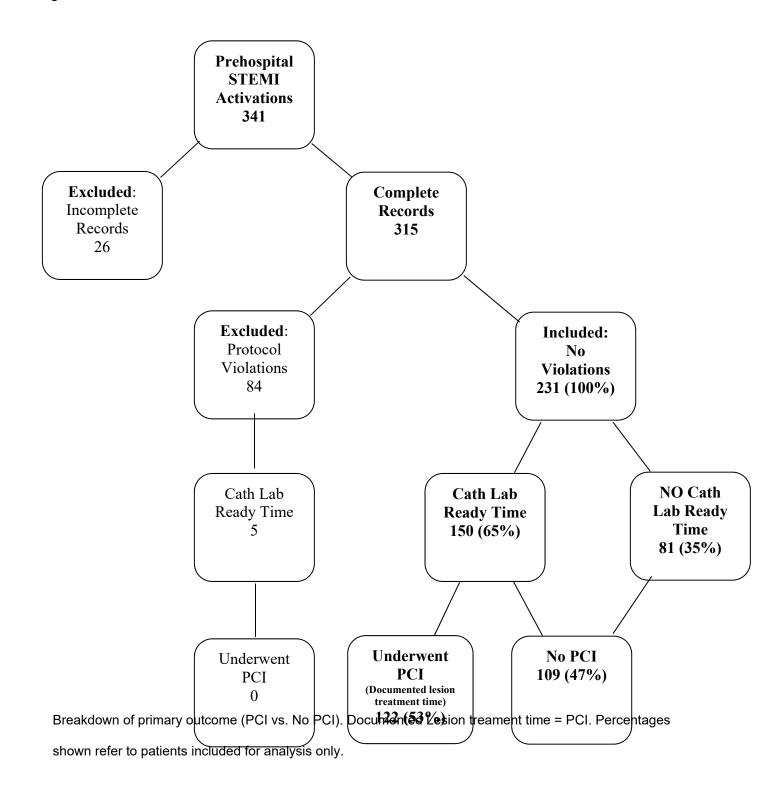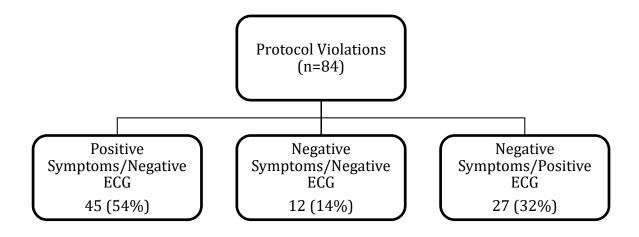
Code STEMI protocol compliance requires that the patient have symptoms consistent with ischemia (chest discomfort, shortness of breath, nausea, etc) + an ECG consistent with a STEMI. The 84 initially identified Code STEMI patients were cancelled secondary to protocol violation as described.

Table 1: Characteristics of Included Patients

	Intervention	No Intervention	Total
	122 (52.8%)	109 (47.2%)	231(100%)
Gender			
Male	84 (36.3%)	79 (34.1%)	163 (70.6%)
Female	38 (16.5%)	30 (12.9%)	68 (29.4%)
Race			
White	88 (38.0%)	52 (22.5%)	140 (60.6%)
Non -White	34 (14.7%)	57 (24.6%)	91 (39.3%)
Age			
Mean	58.1 (95% CI 55.9 to 60.4)	63.4 (95% CI 60.6 to 66.4)	60.7 (95% CI 58.9 to 62.5)
Arm Pain			
Yes	47 (20.3%)	20 (8.65%)	67 (29.0%)
Asthma			
Yes	2 (0.8%)	9 (3.8%)	11 (4.7%)
Bundle Branch Block			
Yes	7 (3.0%)	24 (10.3%)	31 (13.4%)
Cancer			
Yes	4 (1.7%)	14 (6.0%)	18 (7.7%)
COPD*			
Yes	2 (0.8%)	10 (3.0%)	12 (5.1%)
Diabetes			
Yes	18 (7.7%)	33 (14.2%)	51 (22.0%)

Heart Rate			
Mean	82.2 bpm (95% CI 77.3 to 87.2)	102.2 bpm (95% CI 95.2 to 109.2)	91.7 bpm (95% CI 87.4 to 96.1)
Hypertension			
Yes	65 (28.1%)	81 (35.0%)	146 (63.2%)
LVH**			
Yes	11 (4.7%)	40 (17.3%)	51 (22.0%)
QRS Duration			
Mean	99.7 (95% CI 94.6 to 104.8)	109.6 (95% CI 104.5 to 114.8)	104.5 (95% CI 100.7 to 108.1)

*Chronic Obstructive Pulmonary disease

** Left Ventricular Hypertrophy

Table 2: Unadjusted OR and Adjusted OR for Increased Likelihood to NOT Undergo PCI

	Unadjusted		Adjusted	
	Odds Ratio	95% CI	Odds Ratio	95% CI
Age				
10 year interval increase	1.31	1.09 - 1.59	1.42	1.11 - 1.81
Arm Pain**				
Yes	0.36	0.20 - 0.66	0.35	0.16 - 0.73
Asthma				
Yes	5.41	1.14 - 25.62	--	--
BBB				
Yes	4.64	1.91 - 11.27	5.66	1.91 – 16.76
Cancer				
Yes	4.36	1.39 - 13.67	--	--
COPD				
Yes	6.07	1.30 - 28.36	--	--
Diabetes				
Yes	2.55	1.34 - 4.88	--	--
Heart Rate				

10 beat interval increase	1.23	1.12 - 1.36	1.21	1.08 - 1.36
Hypertension				
Yes	2.58	1.47 - 4.54	--	--
LVH				
Yes	5.85	2.81 - 12.16	4.63	2.03 - 10.53
QRS Duration				
	1.01	1.00 - 1.03	--	--
Race				
Non -White	2.83	1.64 - 4.89	3.53	1.76 - 7.08

** Arm pain was the only variable which was associated with an *increased likelihood to undergo PCI* with an AOR of 2.94 (95% CI 1.36 - 6.25).

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