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Process Factors Affecting Reperfusion Time in Patients Presenting with ST-segment Elevation Myocardial Infarction (STEMI)

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Process Factors Affecting Reperfusion Time in Patients Presenting with ST-segment Elevation Myocardial Infarction (STEMI)

A dissertation submitted in partial fulfillment of the requirements for the degree of Doctor of Philosophy at Virginia Commonwealth University.

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List of Abbreviations

Acute myocardial infarction (AMI) - Ischemia of the myocardium caused by an occluded coronary artery.

Door to balloon time (D2B) - The measurement of the amount of time from patient arrival to reperfusion by balloon angioplasty.

Electrocardiogram (ECG) – A measurement of the electrical signals produced by the beating of the heart.

First medical contact to balloon time (FMC) - The measurement of the amount of time from the patient first medical contact, usually EMS, to reperfusion by balloon angioplasty.

Percutaneous coronary intervention (PCI) - Any intervention preformed through percutaneous access to the arterial system, in order to reopen an occlusion of the coronary arteries.

ST-segment elevation myocardial infarction (STEMI) - AMI with elevation of the ST-segment of the PQRST complex on a standard 12-lead EKG.

The American College of Cardiology (ACC) - A non-profit medical association that establishes qualifications and awards credentials upon cardiovascular specialists.

T**he American Heart Association (AHA)** - A non-profit organization in the US that advocates for proper cardiac care in order to reduce rate of disability and death caused by cardiovascular disease and stroke.

Abstract

PROCESS FACTORS AFFECTING REPERFUSION TIME IN PATIENTS PRESENTING WITH ST-SEGMENT ELEVATION MYOCARDIAL INFARCTION (STEMI)

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A dissertation submitted in partial fulfillment of the requirements for the degree of Doctor of Philosophy at Virginia Commonwealth University.

Virginia Commonwealth University, 2020.

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An ST-segment myocardial infarction (STEMI) occurs when the blood flow to the myocardium is suddenly and completely blocked causing the myocardium to become ischemic. A STEMI is a life-threatening condition that necessitates emergent medical treatment. Research has shown that longer reperfusion times are associated with negative patient outcomes. Therefore, time is critical in the treatment of a STEMI. The purpose of this study was to analyze the process factors involved with the identification and treatment of a STEMI and to develop statistical models to determine which factors have a statistically significant impact on reperfusion times at both the overall and individual facility levels.

Retrospective data, covering a three-year period, was collected from four hospitals in the Las Vegas area. A total of 647 cases were analyzed using multiple

regression analysis. The results of these analyses established overall and individual facility level models for both Door to balloon time (D2B) and First medical contact to balloon time (FMC). The results showed that the process factors Prehospital STEMI activation, Cardiologist arrival time, Lifesaving measures, Door to ECG time, Regular versus off hours, Critical diagnostics exams, and Door to first MD time all had a statistically significant impact on Door to balloon time while accounting for over 40% of the explained variance. The process factors EMS transport time, Prehospital STEMI activation, Cardiologist arrival time, Lifesaving measures, Door to ECG time, Regular versus off hours, and Critical diagnostics exams all had a statically significant impact on First medical contact to balloon times while accounting for nearly 60% of the explained variance. At the individual facility level, the process factors Prehospital STEMI activation, Door to ECG time, and cardiologist arrival time were present and accounted for significant amounts of the explained variance in nearly all models. Other statistically significant process factors that appeared in only a few models included Regular versus off hours, Lifesaving measures, Critical diagnostic exams, and Cath lab team arrival time.

CHAPTER 1: INTRODUCTION

This chapter provides a brief overview of the significance of cardiovascular disease and coronary artery disease, as well as highlighting the importance of rapid identification and treatment of ST segment myocardial infarctions (STEMI). The efforts to improve STEMI processes are analyzed and the metric of reperfusion time defined. The aims and research questions guiding this study are identified.

Statement of Problem

Coronary artery disease occurs when the blood vessels vascularizing the myocardium slowly become blocked by plaque. As the plaque burden in the coronary arteries increases, the supply of oxygen-rich blood is decreased. This creates a supply-demand mismatch resulting in progressive clinical symptoms and eventually myocardial cell death. Subsequently, patients are at a much higher risk for plaque rupture or thrombosis causing a myocardial infarction (MI), otherwise known as a heart attack. While there are multiple types of heart disease (e.g., coronary artery disease, hypertensive heart disease, cardiomyopathy, and valvular heart disease), coronary artery disease is potentially the most dangerous.

Myocardial infarctions are generally classified as either a non-ST segment elevation myocardial infarction (NSTEMI) or an ST segment elevation myocardial infarction (STEMI) based on changes in the patient's electrocardiogram (ECG). However, a STEMI is the deadliest type of MI, occurring when a coronary artery becomes blocked, suddenly and complete stoppage of all blood flow to a portion of the heart. The myocardium, perfused by the blocked coronary artery, becomes ischemic and the tissue begins to die. A STEMI can present with a number of different symptoms; however, some of the most common are chest pain or tightness, difficulty breathing, pain in the left arm, shoulder, upper back or jaw. (Achar, Kundu, & Norcross, 2005). STEMIs represent approximately 30-45% of all heart attacks (Afolabi et al., 2007). It is imperative that these symptoms be recognized quickly, and immediate medical attention sought, due to the fact that a STEMI is considered a life-threatening emergency. Reperfusion time is one of the most critical factors in outcomes and survivability of STEMI patients.

The most recent data from American Heart Association (AHA) indicates that cardiovascular disease accounts for over 800,000 deaths in the United States (US) each year (Benjamin et al., 2017). Data from the U.S. Centers for Disease Control and Prevention (CDC) reveal cardiovascular disease to be the number one cause of death in adults (Centers for Disease Control and Prevention, 2005). The AHA estimates that 790,000 people experience a myocardial infarction (MI) annually. Of those, approximately 114,000 die as a result of the MI (Benjamin et al., 2017). These estimates are significantly lower than in previous studies. For example, in 2012 Horst, Stuart, McKinsey, and Gambler estimated that approximately 1.1 million people, annually, were diagnosed with acute myocardial infarction (AMI) due to coronary artery disease. Of those 1.1 million, approximately 350,000 were predicted to die as a result of the AMI (Horst, Stuart, McKinsey, and Gambler, 2012). The reduction in mortality rates between the two studies is likely due, in part, to the efforts of agencies such as the American Heart Association and the American College of Cardiology (ACC).

The AHA and ACC have established evidence-based treatment guidelines for the treatment of STEMI in order to improve patient outcomes. These guidelines established the importance of shorter reperfusion times in STEMI patients. Reperfusion time is defined as the amount of time from the onset of a STEMI to reperfusion of the culprit coronary artery (O'Gara et al., 2012). The two main metrics of reperfusion time that are routinely measured in hospitals are door to balloon time (D2B) and first medical contact to balloon time (FMC). Door to balloon time is the amount of time from the patient's arrival at the hospital to successful reperfusion by balloon angioplasty. First medical contact to balloon time (FMC) is the amount of time from the patient's first contact with medical personnel, most often EMS personnel, to successful reperfusion by balloon angioplasty (O'Gara et al., 2012)..

All medical facilities treating patients presenting with a STEMI will have dedicated processes and protocols designed to streamline the identification and treatment of STEMIs. However, the STEMI process inherently contains a number of steps or process factors that do have the potential to impact an individual facility's reperfusion times. STEMI process factors, which remain constant from facility to facility, are routinely measured for reporting to various agencies as well as facility-specific performance improvement initiatives. These process factors include the time of day and day of the week, mode of arrival of the patient, the possibility of pre-hospital STEMI protocol activation, pre-hospital electrocardiogram (ECG), emergency medical services (EMS) transport time, the door to triage time, the door to first ECG time, the door to first physician contact time, cardiac catheterization (hereafter referred to as 'cardiac cath' or "cath') lab team response time, interventional cardiologist arrival time and the presence of other factors that can delay PCI such as lifesaving measures, critical diagnostic exams, and anatomical variances. A diagram depicting the steps of the STEMI process is presented in Figure 1.

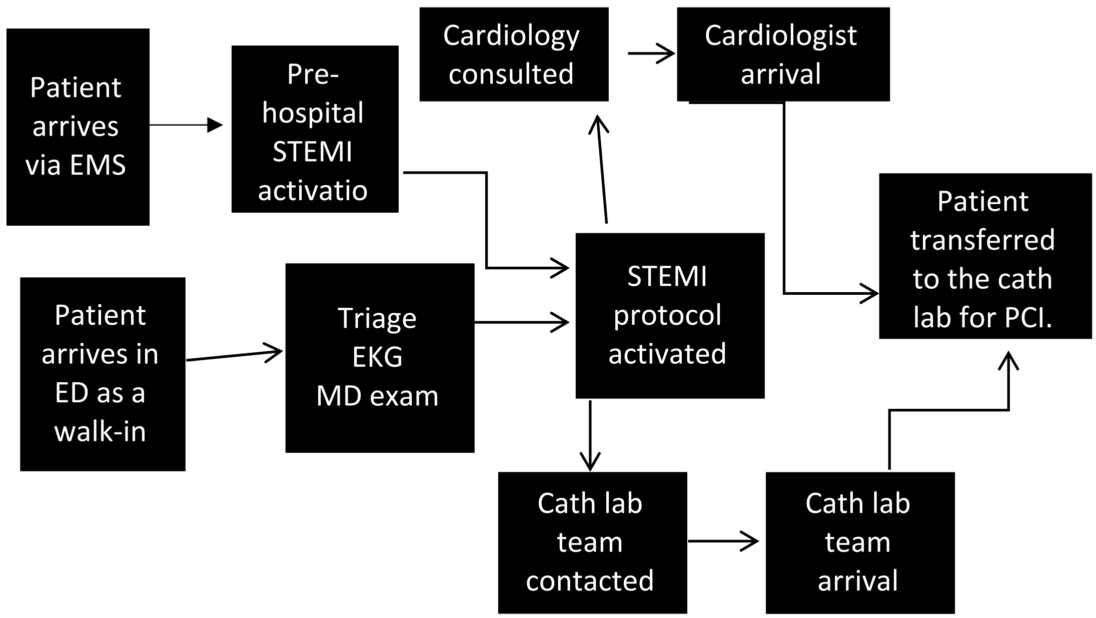

Figure 1. STEMI process flowchart

Patients can present to the hospital in one of two ways: transported by EMS or by civilian means. Patients transported by EMS may have already had a pre-hospital ECG and, in some cases, the STEMI protocol is activated by EMS, termed pre-hospital activation. All patients need to be triaged prior to treatment. The AHA/ACC guidelines stress the importance for hospital staff to be trained to recognize signs and symptoms of patients suffering from a STEMI. Patients presenting with possible STEMI should have a 12-lead electrocardiogram (ECG) performed urgently (O'Gara et al., 2012). Not all STEMI patients present with the classic symptoms of chest pain, shortness of breath, and pain in the left arm; therefore, it is critical that the staff triaging emergency department patients are aware of atypical presentations of STEMI (Borden et al., 2012) . Once the

ECG is complete the emergency department physician examines the patient and confirms the diagnosis of STEMI. From this point, it is imperative that the emergency department activates the STEMI protocol if not already active, as well as contact the cardiac cath lab and interventional cardiologist. Once the cath lab team and interventional cardiologist arrive, the patient is transported to the cath lab to undergo percutaneous coronary intervention. These process factors can impact reperfusion times; however, the extent of their impact, with regards to one another, has not been studied to date. A comprehensive analysis of these process factors and their impact on reperfusion time will provide a deeper understanding of the STEMI process as well as significant evidence for performance improvement measures.

Significance

For patients suffering from a STEMI, reperfusion times are critical. Damage to the myocardium from a STEMI can be debilitating and, in some cases, even fatal. However, there is a significant amount of evidence showing that shorter ischemic times during a STEMI are associated with reductions in significant myocardial damage. Subsequently research has shown that the reperfusion times can also have a significant impact on overall patient outcomes (Antman, 2008; Bates & Jacobs, 2013; Bradley et al., 2006; De Luca et al., 2004). In fact, reperfusion time became such an important factor in patient outcomes that the AHA and ACC collaborated to research, develop, and disseminate best practice guidelines for the treatment of STEMIs in 1990 (O'Gara et al., 2012). Possible changes to the AHA and ACC STEMI guidelines highlight the need for continued research into factors impacting reperfusion times.

Currently there are a number of research studies focusing on STEMI process factors and their impact on reperfusion times; however, these studies tend to focus on a few process factors and neglect to take into account all of the other STEMI process factors involved. The process factor of the patient's mode of arrival was highlighted in a 2014 study by Bansal et al. (2014) who found that patients arriving by ambulance had significantly shorter triage times as well as door to balloon times. Pre-hospital ECG usage and cardiac cath lab team availability have also been studied and have been shown to significantly impact reperfusion times (Afolabi, Novaro, Pinski, Fromkin & Bush, 2007, Hutchison et al., 2009; Kahlon et al., 2016; Lairez et al., 2009; Magid et al., 2005). A 2006 article highlighted strategies to significantly reduce reperfusion times (Bradley et al., 2006) . Bradley et al noted that modifying cath lab team arrival time and physician arrival time were both significant strategies in reducing reperfusion times. While some of these process factors have been examined previously, no studies have been found that seek to determine which of these factors have the greatest impact on reperfusion times. Because of this gap in the knowledge, a deeper understanding of these how significantly these factors impact on reperfusion time is necessary. Furthermore, the development of a series of statistical models individualized for each participating facility could prove invaluable to ongoing process improvements in the STEMI protocol. The aforementioned analysis of the process factors associated with the STEMI process ultimately provided caregivers with the information necessary to improve STEMI reperfusion times and subsequently patient outcomes.

Purpose and Aims

While multiple studies have shown evidence of the impact of reduced reperfusion times on rates of myocardial damage, very few have analyzed more than one or two of the process factors that affect reperfusion times. In fact, no study has been found, to date, identifying and analyzing all of the process factors involved with the treatment of a STEMI. Process factors such as the use of pre-hospital ECG, mode of transport, the availability of the cardiac cath lab team, and cardiologist response time can all impact the reperfusion time. An in-depth statistical analysis of these factors and their impact on reperfusion times can provide invaluable information to hospitals as well as the cardiology community as a whole.

This study sought to identify and analyze multiple process factors involved with the treatment of a STEMI. This study was conducted as a non-experimental retrospective statistical analysis of all of the factors involved with the treatment of a STEMI in order to determine which have the greatest impact on reperfusion time. This study was conducted using data extracted from the STEMI databases of four local hospitals in Las Vegas, Nevada. The data was extracted and analyzed in order to determine which factors have the greatest impact on reperfusion times and to develop a series of statistical models of these factors in order to help educate individual facilities regarding the impact of the process factors. The results of this study will help to expand the base of knowledge regarding the treatment of patients presenting with a STEMI as well as inform individual facilities of which process factors should be focused on in order to improve reperfusion times.

This study was guided by two main aims.

Aim #1: Analyze the process factors involved with the identification and treatment of patients presenting with a STEMI. This analysis will allow us to determine if there is a single factor or combination of factors that significantly impacts the reperfusion times in STEMI cases. This process will generate results that can be used to further inform current guidelines.

Aim #2: Develop comprehensive statistical models of all the STEMI process factors and the degree to which they impact reperfusion times in patients presenting with a STEMI, for individual hospitals. These statistical models will act as guides for each hospital to help determine which factors their improvement efforts would be best focused on, in order to shorten reperfusion times, thus, improving patient outcomes.

Research Questions and Hypotheses

The research questions that guided the study are:

1. Which process factor(s) has a statistically significant impact on the door to balloon time in patients presenting with a STEMI, while controlling for the factors of age, gender and history of coronary artery disease, and history of coronary artery bypass grafts?
2. Which process factor(s) has a statistically significant impact on the first medical contact to balloon time in patients presenting, via EMS, with a STEMI, while controlling for the factors of age, gender and history of coronary artery disease, and history of coronary artery bypass grafts?
3. Which process factor(s) has a statistically significant impact on the door to balloon time in patients presenting with a STEMI, at the level of each

individual facility, while controlling for the factors of age, gender and history of coronary artery disease, and history of coronary artery bypass grafts?

4. Which process factor(s) has a statistically significant impact on the first medical contact to balloon time in patients presenting, via EMS, with a STEMI, at the level of each individual facility, while controlling for the factors of age, gender and history of coronary artery disease, and history of coronary artery bypass grafts?

The hypotheses are as follows:

H_A1: There is a single process factor or combination of process factors that have a statistically significant impact on the door to balloon times of patients presenting with a STEMI.

H_01: There are no process factors that have a statistically significant impact on the door to balloon times of patients presenting with a STEMI.

H_A2: There is a single process factor or combination of process factors that have a statistically significant impact on the first medical contact to balloon times of patients presenting with a STEMI.

H_02: There are no process factors that have a statistically significant impact on the first medical contact to balloon times of patients presenting with a STEMI.

Analytical Approach

This study used routinely collected data on STEMI process factors from each facility. This data is collected and stored in each facility's individual database for reporting to the AHA Mission: Lifeline program as well as the ACC database. Once Institutional Review Board approval was obtained and the necessary approvals at each facility were obtained, the data was extracted and analyzed. The population of the study included all patients diagnosed and treated for a STEMI at the four participating hospitals in the Las Vegas. This sample included all patients presenting to one of the four facilities in Las Vegas with the diagnosis of STEMI, between 01 January 2015 and 31 December 2017. The inclusion criteria for this study included all patients presenting to one of the four participating facilities in Las Vegas with the diagnosis of STEMI who subsequently underwent PCI to achieve coronary reperfusion. The exclusion criteria consisted of all patients sent for emergent coronary artery bypass surgery (CABG), expired prior to PCI completion, were found to have no coronary artery disease, or for whom the STEMI activation was canceled. The statistical analyses conducted in this study included basic descriptive statistics followed by multiple linear regression modeling of the entire sample and a subgroup analysis stratified by individual facilities.

Summary

This chapter provided a brief overview of the significance of heart disease and ST-segment elevation myocardial infarction (STEMI). It has identified a clear gap in the knowledge regarding the process factors impacting reperfusion times as well as identified the measurements of door to balloon time and first medical contact to balloon time. Finally, this chapter had presented the aims of the proposed study as well as the theoretical framework that will guide the subsequent analyses. Chapter two will provide a comprehensive review of current literature regarding STEMI and the process factors involved. Chapter three will review the methodology used in the study including research design, sampling, data collection and statistical analyses. Chapter four will report the results of the statistical analyses and modeling. Finally, chapter five will discuss how the results impact STEMI programs as well as highlight limitation to the study and opportunities for suture research.

CHAPTER 2: LITERATURE REVIEW

The previous chapter introduced the topic of STEMI and established the importance of reperfusion times. Chapter one also discussed the STEMI process as well as identifying the aims and research questions that guided this study.

This review of the literature includes a discussion of published research regarding the process factors impacting reperfusion times in patients presenting with a ST–elevation myocardial infarction (STEMI). In the review a number of process factors have been identified and are discussed with relation to their impact on reperfusion times in STEMI patients. Discussions regarding current heart disease statistics, current and future STEMI guidelines, and the impact of ischemic time on patient outcomes are also included. Finally, the Donabedian model of Structure-Process-Outcomes (Donabedian, 2005) is presented as the theoretical framework, to be used to investigate the process factors impacting reperfusion times in patients presenting with a STEMI.

Introduction

Heart disease affects millions of people worldwide every year. Data collected by the U.S. Centers for Disease Control and Prevention (CDC) have consistently shown heart disease to be the number one cause of death in the United States for the past 80 years (Centers for Disease Control and Prevention, 2005). While there are multiple types of heart disease, coronary artery disease is potentially the most dangerous. Coronary artery disease occurs when the blood vessels vascularizing the myocardium slowly become blocked by plaque. This causes a reduction in the amount of oxygen rich blood getting to the myocardium. As the coronary artery occlusion grows, the subsequent area of myocardium will become ischemic. This can cause a number of clinical symptoms including chest pain and tightness, shortness of breath, and ECG changes. Heart disease puts patients at a much higher risk for the formation of a thrombus or a plaque rupture, both of which usually result in a myocardial infarction (MI). The American Heart Association's most recent statistical report highlights the continued prevalence and dangers of heart disease in the U.S. Coronary artery disease accounts for 1 of every 7 deaths in the U.S. The AHA estimates that approximately 790,000 people in the U.S experience a myocardial infarction each year. Of those, 110,000 will die (Benjamin et al., 2017).

Relevance to the Medical Community

The topic of heart disease is relevant to the medical community for a number of reasons. Rates of cardiovascular disease are expected to continue to rise in the coming years. In fact, experts from the American Heart Association (AHA) project that by the year 2030 over 40% of the US population will have some type of cardiovascular disease (Heidenreich et al., 2011). Heart disease accounted for over 610,000 deaths in 2013, representing 193.3 deaths per 100,000 people in the US. Current estimations indicate that over 26 million adults or 11.3% of the population in the US suffer from heart disease. In 2010 3.7 million people were discharged from a hospital with heart disease as their primary diagnosis. That same year physician's office visits with heart disease as the primary diagnosis reached 12.4 million (Centers for Disease Control and Prevention, 2005). These staggering numbers demonstrate the prevalence of heart disease among

Americans. Cardiovascular disease is a significant burden to its sufferers as well as the medical community as a whole. The AHA project that medical costs associated with heart disease will triple between 2010 and 2030, from $273 billion to $818 billion.

ST Segment Elevation Myocardial Infarction (STEMI)

Myocardial infarctions are classified into two main types: ST-segment elevation myocardial infarctions (STEMI) and non-ST-segment myocardial infarctions (NSTEMI). By far the most dangerous type of MI is a STEMI. STEMIs are estimated to represent approximately 30-45% of all coronary artery diseases (Afolabi, Novaro, Pinski, Fromkin, & Bush, 2007). A STEMI occurs when a coronary artery becomes suddenly and completely blocked, stopping all blood flow to a portion of the heart. The myocardium in this area becomes ischemic and begins to die. This can cause a number of different symptoms; however, some symptoms are more common: chest pain or tightness, difficulty breathing, pain in the left arm, shoulder, upper back or jaw (Achar, Kundu, & Norcross, 2005). These symptoms must be recognized quickly, and immediate medical attention given because a STEMI is a life-threatening emergency.

Treatment of a STEMI involves restoring blood flow in the occluded artery, thereby achieving reperfusion of the ischemic myocardium and halting muscle cell death. Restoration of blood flow can be achieved in a number of ways; however, percutaneous coronary intervention (PCI) is the recommended first line treatment for STEMI (Cooper, 2015; O’Gara et al., 2012). PCI is conducted through the use of balloons and stents inserted through the arterial system via a catheter. The balloon is inflated at the site of the blockage. Stents are often inserted to maintain arterial patency. The most current best practice guidelines state that if PCI is not immediately available then thrombolytic therapy is the next best choice.

Thrombolytic therapy involves the use of thrombolytic drugs to dissolve blood clots causing the coronary occlusion. Patients who receive thrombolytic therapy will often undergo PCI as soon as it becomes available. In extreme cases where PCI has failed or there is a complication that cannot be fixed through a percutaneous approach, emergency coronary artery bypass grafts should be performed in order to bypass the blocked blood vessels (O'Gara et al., 2012).

Ischemic time and its impact on outcomes

A STEMI is caused by a blockage resulting in reduced or no blood flow to a portion of the myocardium. As the blood vessel remains blocked, the ischemic myocardium begins to die, causing damage to the heart muscle. This damage can quickly become debilitating and, in some cases, fatal if not treated in a timely manner. Most studies agree that longer ischemic times are associated with higher mortality rates (Antman, 2008; Bates & Jacobs, 2013; Bradley et al., 2005; Bradley et al., 2006; De Luca, Suryapranata, Ottervanger, & and Antman, 2004) . A 2004 study addressed the relationship between door to balloon times and mortality rates (De Luca et al., 2004) by focusing on patients (n = 1791) presenting with a diagnosis of STEMI and were treated with primary PCI. The authors examined the relationship between ischemic time and 1-year mortality and plotted it using a quadratic regression model. A Cox proportional hazards model was used to calculate relative risks adjusted for a number of patient characteristics and comorbidities that were related to ischemic time (e.g., age, gender, presence of diabetes mellitus and history of previous revascularization). After adjustments for these factors the study showed that each 30 minutes of delay in treatment time increased the risk of 1-year mortality by 7.5% (De Luca et al., 2004) .

Most experts agree that longer ischemic times are correlated with higher mortality rates; however, there is also data to show that this is not always the case. A study in the *New England Journal of Medicine* analyzed trends in door to balloon times and in-hospital mortality rates from July 2005 to June 2009 at 515 hospitals participating in the CathPCI Registry (Menees et al., 2013) . The sample included 96,738 patients diagnosed with a STEMI and treated with PCI. The results showed a marked decline in the median door to balloon times across the study timeline. From July 2005 to June 2006 the median door to balloon times in the sample was 83 minutes. While the final 12 months of the study, from July 2008 through June 2009 showed a median door to balloon time of only 67 minutes ($p<0.001$). Despite this significant difference the in-hospital mortality rate among the sample remained virtually the same (Menees et al., 2013) . Although it appears that there is conflicting data the AHA and ACC still operate under the idea that door to balloon time is closely associated with mortality rates in patients diagnosed with a STEMI.

STEMI Process and Protocols

All medical facilities treating patients with STEMIs have dedicated processes and protocols built to streamline the triage and preparation process to lower door to balloon times. These protocols focus on a number of factors that will impact the program development. It is essential for the emergency department to have optimal communication with EMS personnel to facilitate efficiency with pre-hospital STEMI protocol activations as well as a pre-hospital electrocardiogram (ECG) (Afolabi et al., 2007; Hutchison et al., 2009; Kahlon et al., 2016; Farshid et al., 2015). A major concern when developing a STEMI program is staffing optimization in the emergency department, cardiac cath lab, cardiothoracic surgery, and intensive care/cardiac care units. The personnel in these departments need to be well trained and experienced as well as demonstrate excellent teamwork. Likewise, the physicians involved should also be well trained, experienced and have a good working relationship with the staff in their respective departments. Finally, the hospital administration needs to be willing to put in the effort and funding in order to meet the needs for accreditation. All of these departments working together will provide the best possible care for STEMI patients (Borden et al, 2012).

Figure 2 illustrates the STEMI process common to most facilities. A patient usually presents to the hospital in one of two ways, via EMS or as a walk-in. Patients transported by EMS will have already been triaged and, in some cases, the STEMI protocol is activated by EMS. This is termed pre-hospital activation. Patients that come in via civilian means need to be triaged prior to treatment. It is important for hospital staff to be trained to recognize signs and symptoms of patient suffering from a STEMI. Patients presenting with possible STEMI should have a 12-lead electrocardiogram (ECG) performed urgently. It should also be noted that not all STEMI patients present with the classic symptoms of chest pain, shortness of breath, and pain in the left arm. It is critical that the staff conducting triage in the emergency department patient is aware of atypical presentations of STEMI (Borden et al., 2012) . Once the ECG is complete the emergency department physician will examine the patient and confirm the diagnosis of STEMI. From this point, it is imperative that the emergency department activates the STEMI protocol, if it is not already active, as well as contacts the cardiac cath lab and interventional cardiologist. The patient will be transported to the cath lab to undergo PCI once the cath lab team and interventional cardiologist arrive.

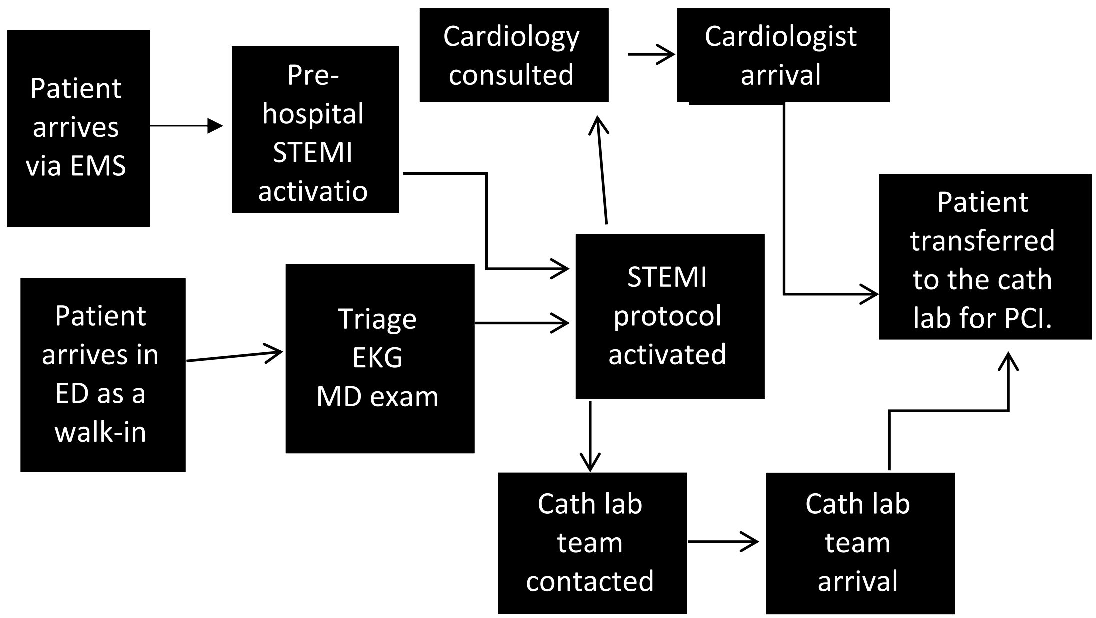

Figure 2. STEMI process flowchart

AHA and ACC guidelines

The American Heart Association (AHA) and the American College of Cardiology (ACC) have developed best practice guidelines regarding the treatments of patients presenting with a STEMI. While these guidelines continue to evolve as new research becomes available, there are some aspects that remain constant. These guidelines define reperfusion time, also known as the door to balloon time, as the amount of time from the point a patient enters the medical facility to the time that reperfusion of the culprit coronary artery is achieved (O'Gara et al., 2012).

In 2002 the Centers for Medicare and Medicaid Services (CMS) as well as the Joint Commission added door to balloon time to the list of performance measures for reporting (Bates & Jacobs, 2013). Recognizing that ischemic time is one of the most important factors in the treatment of STEMI, the AHA and ACC have developed programs to help facilitate the development of hospital-based STEMI protocols. These programs include the Door-to-Balloon Alliance in 2006 and Mission: Lifeline in 2007. These programs help to develop and standardize STEMI processes of care (Bates & Jacobs, 2013). These programs coupled with the AHA and ACC guidelines give hospitals a framework on which to develop their respective programs. Once a hospital has developed a STEMI program, they are required to have at least 75% of their STEMI cases per year to achieve a door to balloon time of 90 minutes or less in order to be accredited by the AHA and ACC as a STEMI treatment center.

A report from the Mission: Lifeline project highlighted the effectiveness of the program (Jollis et al., 2016). The Mission: Lifeline program established leadership teams and coordinated protocols as well as providing feedback to 484 hospitals and 1253 EMS agencies across the United States. The report analyzed 23,809 patients with acute STEMIs treated between July 2012 and December 2013. The sample of patients for this study was taken directly from these facilities. Prior to this study, the authors estimate that up to 50% of patients diagnosed with STEMI are not treated within the STEMI guideline goals (Jollis et al., 2016). The results indicated statistically significant improvements in the FMC to balloon time in patients that presented via EMS and those transferred from other facilities. The amount of EMS patients being treated within the guideline window increased from 50% to 55% ($p < 0.001$). Patients transferred from other facilities treated within the guidelines window increased from 44% to 48% with a p-value of 0.002. This data shows that the Mission: Lifeline program is successful in their efforts to decrease treatment times for patient presenting with a STEMI.

Recently, CMS removed door to balloon time from its list of core measures for hospital reporting. The rationale behind this decision was that most facilities were making the door to balloon times already. An incentive was no longer necessary. This action alleviated some of the pressure on facilities to continue to improve their door to balloon times. However, it is expected that renewed interest in the issue of door to balloon time will occur when the current ACC/AHA guidelines are enforced for accreditation purposes. The 2012 ACC/AHA guidelines are currently being used by most facilities; however, the accrediting bodies of the ACC and AHA have yet to adopt these updated guidelines as requirements for hospital accreditation (O'Gara et al., 2012). The implementation of these guidelines by the accrediting bodies of the ACC and AHA will have a significant impact on most hospitals. This move may prompt CMS to again include, what will then be called, first medical contact (FMC) to balloon time in the list of core measures for hospital reporting.

Factors Affecting Door to Balloon Time

While the STEMI process and protocols for each facility are well tested and refined, there are still a number of inherent factors that can greatly impact door to balloon times. Some of these factors are specific to each patient such as patient characteristics that can delay treatment. Dodin focused on a number of factors that impact door to balloon time in patients with a STEMI (Dodin, 2014). These factors included process factors as well as patient characteristics such as age, gender, race, time from symptom onset to arrival, and prior coronary history. The study, conducted in Minot, North Dakota, consisted of all patients (n = 150) presenting to a local hospital with the diagnosis of STEMI from 2009 to 2013. The results indicated that the factors of age and time from symptom onset to arrival were significantly associated with door to balloon times (Dodin, 2014). The results also showed that pre-hospital ECG and pre-hospital STEMI protocol activation were associated with shorter door to balloon times. Patients with pre-hospital ECGs saw a mean reduction in D2B time of 15.74 minutes (p=0.011), as well as a reduction of 14.23 minutes (p=0.046) for pre-hospital STEMI protocol activation.

While some factors impacting door to balloon time are patient based, others derive from the STEMI process itself. Some of these STEMI process factors include the mode of patient arrival, ER triage and treatment time, cardiologist consult time, cath lab contact time, cath lab arrival time, cardiologist arrival time, and finally any complicating factors such as life-saving efforts, or critical diagnostic studies. While some of these factors can and are controlled through policy and procedures, others remain out of the facilities' control (Dodin, 2014).

Mode of arrival. The means by which a patient arrives at the emergency department can have a drastic effect on the possibility of delays in their treatment. It is generally accepted that patients experiencing chest pain or other symptoms of a heart attack should call for an ambulance rather than drive themselves to the hospital. Going to the hospital via ambulance allows the EMS personnel to evaluate and triage the patient prior to arriving at the hospital. Also, patients arriving via ambulance bypass the waiting room and are taken directly to the emergency department for treatment. Transport by EMS will often result in shorter door to balloon times (Bansal et al., 2014; Mathews et al., 2011). Bansal and collogues performed a retrospective review of 136 STEMI patients that present to an urban academic teaching hospital between January 2009 and December 2011 (Bansal et al., 2014). This review showed that patients arriving by any means other than an ambulance, also called walk-in patients, had significantly longer triage times as well as door to balloon times. They found that walk-in patients had a mean door to balloon time of 136 minutes while EMS transported patients had a mean door to balloon time of only 60 minutes (Bansal et al., 2014). A stepwise logistic regression analysis identified the method of hospital entry as the only independent predictor of prolonged a door to balloon time in this study.

A national data registry was used to analyze the records of over 37,000 patients diagnosed with STEMI at 319 different hospitals. The analysis focused on factors affecting their choice to use EMS transport or private transport to the hospital after the onset of symptoms (Mathews et al., 2011). The initial analysis found that only about 60% of the patients used EMS services. Further analysis found that those more likely to use MES services were older patients, patients living farther from the hospital, and patient that were later found to be hemodynamically compromised. However, race, income, and education level were not found to be significant factors in the choice of EMS or private transport (Mathews et al., 2011).

Pre-hospital STEMI protocol activation. A patient's mode of arrival to the hospital determines whether or not pre-hospital STEMI activation is possible. Pre-hospital activation of the STEMI protocol occurs when paramedics or EMTs examine a patient and a preliminary diagnosis of STEMI is determined. This is communicated to the receiving facility and subsequently the facility activates their STEMI protocol, contacts the cardiologist and cath lab team. Pre-hospital activation relies on the signs and symptoms of the patient as well as the use of pre-hospital ECG. When a patient drives himself or herself to the hospital, there is no chance for pre-hospital activation of the STEMI protocol. Pre-hospital activation can significantly reduce door to balloon time by reducing triage time and activating the cardiologist and cath lab team before the patient arrives. A number of studies have shown the benefit of pre-hospital ECG and STEMI activation.

A 2007 study examined a cohort of 167 STEMI patients treated between October 2001 and November 2004 (Afolabi et al., 2007). The study focused on the use of pre-hospital ECG by emergency medical services (EMS) and subsequent door to balloon times. They found that 74% (n = 123) of the cohort was transported via emergency medical services. Of this group, 81% (n = 100) underwent a pre-hospital ECG and a pre-hospital activation of the STEMI protocol was initiated. Subsequently, 15% (n = 18) did not receive an ECG yet the pre-hospital activation was still initiated and the final 4% (n = 5) did not receive an ECG and no pre-hospital activation. The study showed that the patients transported to the hospital via EMS had a mean door to balloon time of 56 minutes while those who drove themselves had a mean door to balloon time of 105 minutes (Afolabi et al., 2007).

A 2009 study found similar results (Hutchison et al., 2009). Hutchison and colleagues conducted a prospective study of 349 patients undergoing primary PCI at a single STEMI-receiving center. The study focused on the impact of pre-hospital 12-lead ECG, triage and STEMI activation on the door to balloon time. The patients were divided into two groups, those who received field ECGs and triage and those that did not. The results show a significant difference between the groups. The mean door to balloon time for the field triage group was 56 minutes (p<0.001) while the non-triage group mean was 98 minutes (p<0.001) (Hutchison et al., 2009).

A recent study in Japan evaluated the usage of a new mobile telemedicine system (MTS) developed to send real-time patient information, such as heart rate, blood pressure, real time ECGs, from ambulances to the receiving hospital (Kawakami et al., 2016). The study focused on the MTS' impact on door to balloon times in STEMI cases. The compared three main groups of patients; those transported on ambulances using the MTS system, those transported on ambulances without the system, and those transferred from another hospital on ambulances not suing the MTS system. The results showed that the MTS group had a significantly shorter door to balloon times than the other two groups. IT is believed that this occurred primarily due to the use of a pre-hospital activation via the MTS system. Physicians had the opportunity to view clinical data as well as a video feed of the patient in the ambulance. This allowed for expedited diagnosis and activation of the STEMI protocol, which subsequently translated to shorter door to balloon times (Kawakami et al., 2016).

The benefits of pre-hospital diagnosis and activation are apparent (Kahlon et al., 2016). The authors conducted a retrospective analysis of 280 consecutive STEMI patients treated with PCI between January 2009 and September 2011. The patients were divided into two groups, those that had a pre-hospital ECG were taken directly to a PCI-capable facility and those that were taken to the closest facility and then diagnosed with a STEMI and subsequently transferred to a PCI-capable facility. The study demonstrated a significant difference in the treatment times; a mean first medical contact time of 79 minutes for the pre-hospital ECG group and a mean of 157 minutes for the other group ($p<0.001$). Further analysis showed that the mortality rate at 1-year for the pre-hospital activation group was half of that of the other group, 4.1%, and 8.3% respectively (P-value = 0.34). However, after adjustments made for age differences in the groups the 62% reduction in mortality in the pre-hospital ECG groups was not considered statistically significant (P-value = 0.19) (Kahlon et al., 2016). The conclusion of this study showed that the use of pre-hospital ECG reduced first medical contact to reperfusion times by 50% and were associated with improved clinical outcomes at 1-year.

It is clear that pre-hospital activation of the STEMI protocol has a substantial impact on the door to balloon times and subsequently patient outcomes. It should also be noted that while researching strategies for improving door to balloon time, Bradley et al. found that the use of pre-hospital activation of the STEMI protocol by either the emergency department physician or EMS personnel resulted in twice the number of cases in which the cardiac cath lab team was called in but ultimately PCI was not necessary (Bradley et al., 2006). These false alarms have the potential to become costly to a high-volume facility. It is for this reason that extensive training should be provided for personnel expected to activate the STEMI protocol.

Cath lab staff availability and arrival (time of day, day of week). While time is one of the most critical factors in the treatment of a STEMI, the time of day and day of the week that the patient presents to the hospital can end up being a significant factor in the door to balloon time. Most cath labs are staffed fully during the standard hours of 7 am to 5 pm on weekdays and rely on staff being on call for the rest of the time. When staff members are on call, they are not usually in the facility and, therefore, will need to be called in when the STEMI protocol is activated. The maximum response time varies and is usually based on hospital policy. Magid et al. conducted a cohort study of over 33,000 patient diagnosed with a STEMI who were treated with PCI from 1999 through 2002 (Magid et al., 2005). Their results showed that door to balloon times were substantially longer during the off hours. Off hours door to balloon times averaged 116.1 minutes while standard hours door to balloon times averaged 94.8 minutes for a difference of 21.3 minutes ($p < .001$). The study also showed a significantly higher chance of door to balloon times exceeding 120 minutes and well as increased rates of in-hospital mortality for patient presenting during off-hours.

A 2009 study examined the relationship between the time of day and day of week and in-hospital mortality in patients undergoing emergency PCI. Over 2000 cases were examined with the results clearly demonstrating a higher mortality rate among patients undergoing emergency PCI during the night and weekend days as opposed to daytime during the week. PCIs conducted at between the hours of midnight to 0400 had a 5.1% occurrence rate and weekend days had a 3.0% occurrence rate. These numbers are significantly higher than the 1.5% occurrence rate for all other times (Lairez et al., 2009). Similarly, results obtained from a study of 447 US hospitals from 2007 to 2010 showed that patients arriving at a hospital with a STEMI during standard hours had significantly lower mean door to balloon times than those arriving during off-hours (Arrival time impacts treatment for patients with STEMI, 2014).

It is clear that the time of day and day of the week that a STEMI presents is an important factor in the door to balloon times. This is mainly due to the availability of the cardiac cath lab team during off hours. Bradley et al. conducted a multivariate analysis in order to determine strategies for reducing the door to balloon time for STEMI patients. One of the strategies proposed was to expect cath lab staff to respond within 20 minutes when called during off hours as opposed to the standard of 30 minutes. The research demonstrated that this reduction in the response time clearly resulted in statistically significant decreased reperfusion times (Bradley et al., 2006).

ER treatment times. Timely triage, diagnosis, and treatment are necessary to shorten door to balloon times and produce optimal patient outcomes. The process of a patient arriving at the emergency department, being triaged, admitted, diagnosed and treated is vulnerable to a number of different delays. Patients arriving at the hospital by their own transport have to check in at the emergency room and be triaged before a physician can examine and treat them. Due to most emergency departments being consistently busy, this process can take time. All PCI centers will have STEMI protocols in place that prioritize all patients triaged with chest pain or other possible symptoms of an AMI. However, some patients do not present with any of the standard symptoms of an AMI. A study published in 2012 focused on ways to improve door to balloon times in STEMI patients that present with no chest pain (Borden et al., 2012). They analyzed STEMI patients presenting both before and after the changes made by the quality improvement program. The quality improvement program consisted of two phases of integration of proven strategies for decreasing door to balloon times. Phase 1 included a single call STEMI activation system, formal case review sessions and real-time feedback. The second phase brought expanded criteria for rapid ECG triage in order to catch the atypical presentation of some STEMI patients (Borden et al., 2012). The authors compared patients from each of the phases to determine if the quality improvement program has been effective. The results confirmed that the program was effective. The phase 1 results showed a marked difference in the door to ECG times of STEMI patients presenting with chest pain and those without chest pain. The phase 2 results showed that that difference was effectively eliminated and mean door to balloon times decreased as well (Borden et al., 2012).

The possibility of patients presenting with atypical symptoms is only one of a number of factors that can cause delays with STEMI patients in the emergency department. A doctoral dissertation by Sammons (2012) highlights other factors that can cause delays with the triage and identification of patients with AMI (Sammons, 2012). Her study focused on a sample of 286 patients with symptoms suggestive of AMI to analyze the relationships between (a) patient characteristics such as race, age, gender, and symptom presentation, (b) RN characteristics such as age, years of experience, and level of education, and delays of care of patients with symptoms suggestive of an AMI. The results show that both patient characteristics and RN characteristics impact delays in treatment (Sammons, 2012). Non-Caucasian patients were twice as likely to be triaged accurately and patients presenting with chest pain were two and a half times as likely to be triaged accurately which leads to fewer delays of care. The results also showed that neither years of experience nor the RN's level of education were able to predict accuracy of triage. However, RN age was significantly associated with the accuracy (Sammons, 2012). These results clearly show that there are a number of factors involved in the triage and treatment in the emergency department that can have a significant impact on door to balloon times.

Some facilities have made efforts to alleviate possible delays in the emergency department by having pre-hospital activated STEMI cases that are confirmed brought directly to the cardiac cath lab or specific cardiac care unit by EMS upon arrival. Of course, expediting the transfer of STEMI patients to the cardiac cath lab is only possible during standard work hours when the cardiac cath lab team is already in the hospital and available. However, this process has been shown to shorten door to balloon times in other facilities where it has been used. A study of 533 patients admitted between January 2002 and November 2005 with a diagnosis of a STEMI showed significantly shorter door to balloon times for those patients admitted directly to the cardiac unit (Amit, Cafri, Gilutz, Ilia, & Zahger, 2007). Subsequently, the researchers also noted a trend toward reduced 30-day and 1-year mortality rates among the patients who were directly admitted to the cardiac unit. A study in Germany initiated a process by which EMS would bypass the emergency department with STEMI patients deemed eligible for direct PCI (Van de Loo, Saurbier, Kalbhenn, Koberne, & Zehender, 2006). The sample consisted of 74 patients and was matched with a historical control group of patients for analysis. The results showed a significant difference in door to balloon times between the groups. The “ER bypass” groups showed a reduction of 27 minutes in the median door to balloon times over the historical control group (Van de Loo et al., 2006). It is clear that this is a valid strategy to reduce door to balloon times, however; it remains contingent on the availability of the cardiac cath lab team.

Cardiologist arrival. The subject of cardiologist notification and arrival in cases of STEMI has not been well researched. Most facilities have an in-hospital cardiologist who can perform PCI. However, in some areas of the country cardiologists do not work for the hospitals but work for a cardiology group that is contracted with multiple facilities. This setup has the potential to have a single cardiologist on call for STEMIs at multiple facilities at once. This often leads to situations in which the on-call cardiologist has to come from another facility when the STEMI protocol is activated, possibly causing delays in the door to balloon time.

Research by Horst, Stuart, McKinsey, and Gambler identified the responding cardiology groups as a key predictor of the door to balloon time in their study (Horst et al., 2012). This was due, mainly, to the fact that different cardiology groups have different on-call policies and subsequently different mean door to balloon times. Another study by Bradley et al. determined the six strategies that were significantly statistically associated with shortened door to balloon times (Bradley et al., 2006). One of those strategies focused on having an attending cardiologist on site at all times. Their results found that this reduced door to balloon times by an average of 14.6 minutes. This significant reduction in time may limit heart muscle damage. It is clear that this is a factor that can have a significant impact on door to balloon times and warrants further study.

Presence of complicating factors (CPR, etc.). The presence of complicating factors causing delays in door to balloon time has not been a subject of much study. Most of these factors can be attributed to emergency department delays or cardiac cath lab delays. However, it is necessary to take them into account when reviewing factors potentially impacting door to balloon times. Complicating factors include treatment activities that are necessary, yet can still delay door to balloon time, as well as patient characteristics that can cause treatment delays. Some examples of complicating factors are CPR prior to transport to the cath lab, intubation in the emergency department, the need for a computed tomography (CT) scan prior to PCI, or anatomical variants causing difficulty accessing the patient's coronary arterial system. In a study published in the American Journal of Medical Quality, researchers noted that receiving a portable chest x-ray was found to be a key predictor of longer door to balloon times in their study (Horst et al., 2012). These factors are often dictated in the physician's report and are found in the treatment record. However, almost no research has been done to determine the impact of these factors on door to balloon times.

Rationale for Further Study

Research has shown that heart disease and subsequently STEMIs are on the rise in this country. The CDC expects that heart disease will continue to be the number one cause of death in the United States for many years to come. In fact, some estimates show that by 2030 the United States could have as much as 40% of the population diagnosed with heart disease (Heidenreich et al., 2011). This will result in a drastic rise in the number of heart attacks and related deaths each year. These estimates coupled with the continuing rising rates of obesity and diabetes clearly demonstrate a need for continued study on the subject of heart disease, STEMI, and what strategies hospitals can employ in order to achieve best possible patient outcomes.

Imminent changes to the ACC and AHA accrediting body's guidelines are also a cause of concern for many hospitals. The previous ACC/AHA guidelines recommended a door to balloon time of fewer than 90 minutes. However, changes to the guidelines have initiated the idea of first medical contact (FMC) to balloon time (O'Gara et al., 2012). These changes remain simply best practice guidelines and have not yet been adopted by accrediting agencies. These new guidelines will encourage hospital-based STEMI programs to work closely with the local emergency medical services (EMS) in order to focus on changing the initial time metric from door time to first medical contact time (FMC). This change would start the "STEMI clock" as soon as EMS reached the patient. Using FMC as a metric would include EMS transport times in the 90-minute window. There have also been discussions regarding the possibility of shortening the door to balloon or FMC to balloon time to 60 minutes. These changes have the potential to drastically change the landscape of STEMI treatment throughout the country. It is therefore imperative that researchers continue to learn as a much as possible about the factors that affect door to balloon time in order to be better prepared for future changes in the guidelines.

Theoretical Framework

The theoretical framework guiding the proposed study is the Donabedian model of health care quality measurement. The Donabedian model has been extensively used as a theoretical framework in order to analyze and improve the quality of multiple different aspects of health care. In 1966 Avedis Donabedian, a physician and health services researcher at the University of Michigan began developing a conceptual model for examining and evaluating health services as well as the quality of care. His subsequent framework focused on measuring the quality of health care by analyzing the components of the three constructs of the model, structure, process, and outcomes. The model itself is linear and each component or construct is directly affected by the preceding (Donabedian, 2005). Figure 3 shows a graphic of the design of the

Donabedian model.

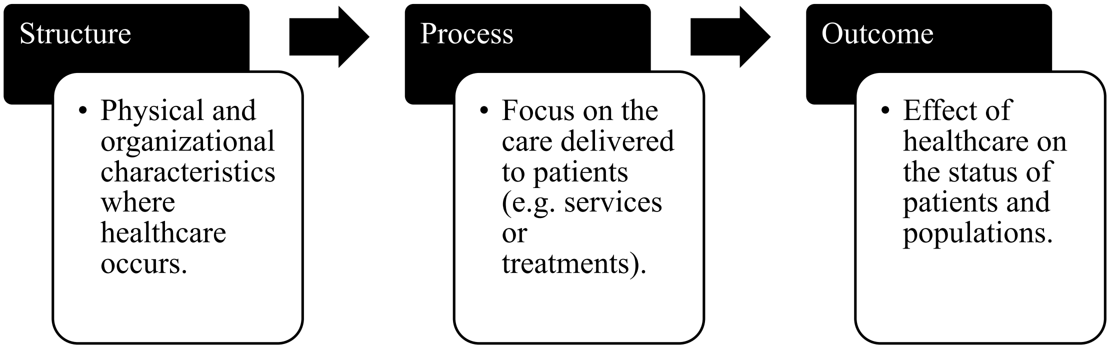

Figure 3. The Donabedian model

Donabedian defined the structure construct as including all of the factors that have an effect on the context in which the care is delivered. This includes facilities, equipment, the organization and qualifications of the staff, and the administrative and support structures. The process construct includes aspects of health care such as provider-patient interactions, leadership, culture of safety, and human resources. The process of evidence-based care as well as departmental protocols such as triage, code response, and security also fall under this construct. The outcome construct is defined as the resulting outcome of the antecedents of structure and process can be further defined in many different ways. Some commonly used indicators of quality outcomes are restoration of function and survival. Outcomes can measure both individual performances as well as collectively become an organizational standard of care (Donabedian, 2005).

Using this basic framework, the STEMI process factors on which data was collected can be associated with the process construct. The measured outcomes of Door to balloon time and First medical contact to balloon time can then be associated with the construct of outcome. Finally, this framework will allow direct correlation of the effects of the process factors, such as mode of arrival and prehospital STEMI activation, on the patient outcomes of the Door to balloon time and First medical contact to balloon time. Figure 4 demonstrates how the Donabedian model framework can easily be applied to the STEMI process.

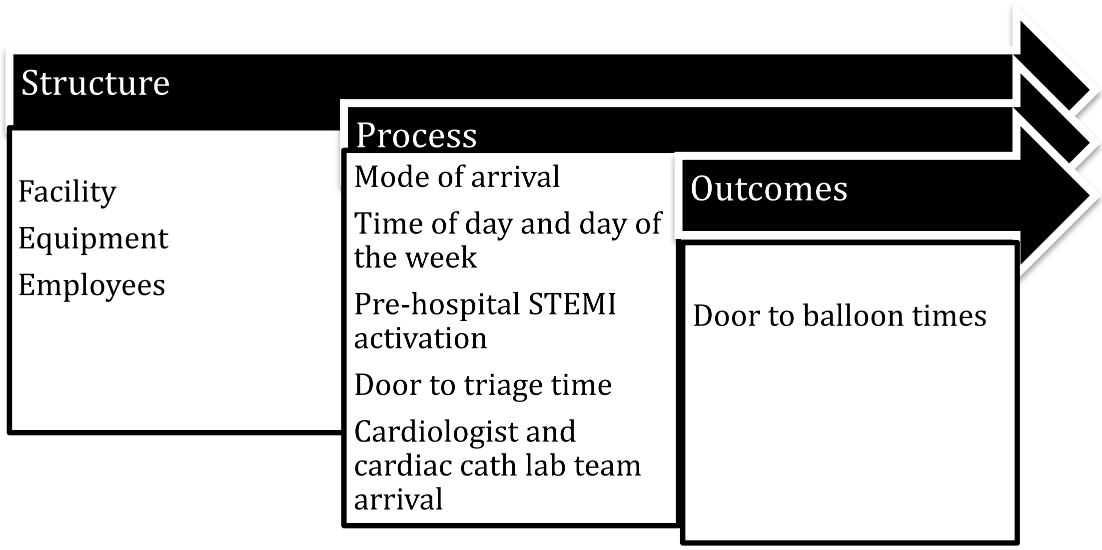

Figure 4. The Donabedian model applied to the STEMI process.

Summary

In summary, a STEMI is a life-threatening medical emergency that necessitates immediate treatment. A STEMI occurs when one of the blood vessels feeding the heart becomes suddenly and completely blocked. This results in a portion of the heart becoming ischemic. If the blood flow is not returned quickly the heart muscle begins to die, this can cause lasting and possibly fatal heart damage. While there is a significant amount of data showing an association between ischemic time and mortality in STEMI patients, there is also data that creates doubt in the validity of this association. However, it is universally accepted that shorter ischemic times are likely to produce better patient outcomes. This has led to the development a number of programs designed to help hospitals to develop policies and protocols for the timely and accurate identification, triage, and treatment of STEMI patients.

These STEMI protocols focus on the identification of patients with symptoms consistent with a STEMI, rapid confirmation of diagnosis, rapid notification of necessary personnel, and the fastest possible treatment in order to minimize cardiac damage. This process truly begins with the patient's transport to the facility and continues with the triage and treatment in the emergency department and culminates with percutaneous coronary intervention in the cardiac cath lab. While quite effective, these STEMI protocols still have inherent factors that can cause delays in triage, diagnosis, protocol activation, and treatment. These delays can and will affect door to balloon time and ultimately patient outcomes.

Factors that can affect door to balloon time include; Mode of patient arrival, the use of pre-hospital STEMI protocol activation, the time of day and day of the week, cath lab team arrival time, cardiologist notification, emergency room triage and treatment delays, and other confounding factors. Research has been conducted on most all of these factors and most of the studies agree that they do impact door to balloon times. However, no research studies were found that analyzes all of these factors concurrently in order to determine which combination of these factors has the greatest impact on door to balloon times. The lack of significant research using all-inclusive models of process factors coupled with the possibility of impending changes to the ACC and AHA STEMI guidelines, calls for further study of these subjects.

This chapter analyzed and presented research on the topics of STEMI and the process factors impacting reperfusion times. The following chapter will present the methodology used including the research design, sampling strategies, data collection, and statistical analyses. Chapter four will report the results of the statistical analyses as well as establish how these results answer the research questions.

CHAPTER 3: METHODOLOGY

Chapter one described the condition known as an ST- segment elevation myocardial infarction (STEMI) and established the importance of all aspects of the STEMI treatment process. Chapter one also outlined the aims, research questions, and hypotheses that guided this study. The second chapter reviewed significant literature on the process factors involved with the identification and treatment of a STEMI as well as detailing the theoretical framework used in this study. This chapter introduces the research design and methodology as well as describes the study setting and sampling method. The measures, dependent and independent variables, and covariates are identified and defined. Finally, the procedures used to extract the data and subsequent statistical analyses are also addressed.

Research Design

The study of process factors affecting reperfusion time in patients presenting with an ST-segment elevation myocardial infarction was a non-experimental, retrospective analysis of secondary data. The impact of STEMI process factors such as the patient's mode of arrival, cath lab team availability, physician arrival, and presence of complicating factors such as CPR prior to PCI, on reperfusion times were examined. The dependent variables were door to balloon time and first medical contact to balloon time. The independent variables examined included the mode of arrival, door to triage time, door to first MD contact time, time of day, day of the week, pre-hospital STEMI activation, pre-hospital ECG, cath lab team arrival time, cardiologist arrival time, EMS transport time, and the presence of complicating factors such as CPR prior to PCI, anatomical variances, or critical diagnostic exams necessary prior to the PCI. Covariates included age, gender, history of CAD and history of CABG.

Setting

The STEMI databases of four designated STEMI-receiving centers in the greater Las Vegas area were used to generate the data for this study. Together, these four facilities accounts for almost 30% of all the hospitals in the Las Vegas area and all are part of a major health care corporation. The facilities agreeing to participate in the research study included; Facility A Hospital, Facility B, Facility C, and Facility D.

Sample

The sample consisted of all patients presenting to one of the participating facilities with a diagnosis of ST-segment elevation myocardial infarction (STEMI) between 1 January 2015 to 31 December 2017. These patients had to have undergone successful percutaneous coronary intervention (PCI) in the cardiac catheterization laboratory under the guidelines of the facility's STEMI protocol. For the purpose of this study, a successful PCI was defined as complete reperfusion of the culprit coronary artery by means of balloon angioplasty.

It was necessary to exclude patients for a number of reasons in this research study. Patients with missing data were excluded. Patients for whom the STEMI activation was cancelled were excluded as were those not initially presenting with a STEMI but whom later developed symptoms. Patients already admitted to the hospital for other diagnoses who subsequently develop STEMI symptoms were also excluded. Patients who underwent cardiac catheterization with negative findings were excluded. Patients that were taken to the surgery for emergency coronary artery bypass grafts (CABG) prior to PCI or due to failed PCI were excluded. Finally, patients that died prior to completion of successful PCI were also excluded.

Study Variables

Dependent variables. The two dependent variables were door to balloon time (D2B) and first medical contact time (FMC). The measure of the amount of time from the arrival of the patient at a medical facility to the restoration of blood flow in the coronary artery via PCI is known as the door to balloon time. The door to balloon time was measured in minutes on a continuous scale. This measure was routinely collected for each case and was used as a dependent variable for statistical analyses conducted in this study. The measure of the amount of time from the first medical contact with the patient to the restoration of blood flow in the coronary artery via PCI is known as the first medical contact to balloon time (FMC). The FMC time was measured in minutes on a continuous scale. This measure is only applicable to patients being transported to the medical facility by EMS. For patients presenting to a medical facility by means other than EMS the first medical contact time will be the same as the arrival time. The FMC measure was routinely collected for cases in which the patient was transported by EMS and was used as a dependent variable for some of the statistical analyses conducted during this study.

Independent variables. The independent variables of the study consisted of a majority of the process factors reported in the literature involved with the identification and treatment of a patient presenting with a STEMI based on the literature. These include: the mode of arrival, regular versus off hours, pre-hospital electrocardiogram

(ECG), the use of pre-hospital activation of the STEMI protocol, door to triage time, door to ECG time, door to first physician contact time, cardiologist arrival time, cardiac catheterization lab team arrival time, lifesaving measures prior to PCI, critical diagnostic exams prior to PCI, anatomical variances causing PCI delay, and EMS transport time. For the purpose of this study, lifesaving measures prior to PCI were defined as CPR or intubation prior to PCI. Critical diagnostic exams prior to PCI were defined as a CT scan performed prior to being transported to the cardiac cath lab. Anatomical variances causing PCI delays were defined as recorded difficulty accessing the patient's coronary anatomy. A list of the independent variables is found in Table 1.

The variable of pre-hospital STEMI activation is measured as either yes or no. Pre-hospital STEMI activation occurs when a patient is being transported by EMS and a STEMI is identified prior to arrival at the hospital. The EMS personnel are able to radio ahead to the receiving facility and activate the STEMI protocol prior to their arrival. The data extracted from the databases only stated the date and time of date that the patient presented. For the purpose of the analysis, the data points of the time of day and day of the week were combined in order to form the variable regular versus off hours. Regular hours were defined as 0700 to 1730 on weekdays and off hours were defined as 1730 to 0700 on weekdays and all day on Saturday and Sunday.

The door to triage time is a measurement of the amount of time between patient arrival and the time of triage. The door to ECG time is the measurement of the amount of time between patient arrival and the first ECG. The door to first physician time is the measurement of the amount of time between the patient arrival and the first exam by a physician.

Table 1. Independent Variables Definitions and their Measurement

Variable	Definition of Variable	Level of Measurement	Measurement
Mode of Arrival	The mode by which the patient arrives at the medical facility (i.e. Ambulance or personal means such as a personally owned vehicle or public transportation.	Dichotomous	EMS or Civilian
Regular vs. off hours	Regular hours – 0700 to 1730 Weekday, Off hours – 1730 to 0700 on weekdays and weekends.	Dichotomous	Regular hours or off hours
Pre-Hospital EKG	Whether or not an ECG was performed by EMS prior to arrival.	Dichotomous	Yes or No
Pre-Hospital STEMI Activation	Whether or not EMS activated the STEMI alert prior to arrival.	Dichotomous	Yes or No
Door to Triage time	Time between the patient's arrival to the facility and the initial triage.	Continuous	Minutes
Door to EKG time	Time between the patient's arrival and the first ECG.	Continuous	Minutes
Door to 1st MD time	Time between the patient's arrival and the first examination by the ER physician.	Continuous	Minutes
Cardiologist Arrival time	Time between the notification of the cardiologist and their arrival at the facility.	Continuous	Minutes

Cath Lab response time	Time between the STEMI activation and the cath lab team arrival.	Continuous	Minutes
Lifesaving measures prior to PCI	Whether or not lifesaving measures were necessary prior to PCI (i.e. CPR, intubation, placement of an intra-aortic balloon pump, or placement of a temporary pacemaker).	Dichotomous	Yes or No
Critical diagnostic exams prior to PCI	Whether or not critical diagnostic exams were necessary prior to PCI (i.e. CT of the head or chest x-ray).	Dichotomous	Yes or No
Anatomical variances causing PCI delay	Whether or not anatomical variances were present that caused PCI delay (i.e. difficult arterial access, occluded arterial access sites, or anomalous coronary arteries).	Dichotomous	Yes or No
EMS Transport time	The amount of time between EMS's first contact with the patient to arrival at the hospital.	Continuous	Minutes
Route of access	The route of arterial access used for PCI (i.e. femoral artery or radial artery).	Dichotomous	Femoral or Radial

The cardiologist response time is the amount of time between the initial contact with the cardiologist and the time that they respond. The cardiologist arrival time is the amount of time between the notification of the cardiologist and their arrival to the hospital. The cardiac cath lab team arrival is the amount of time from the cath lab team notification to the arrival of the third member of the team. With the inclusion of FMC to balloon time as a dependent variable it becomes necessary to also include transport time for all patients presenting via EMS. For this study EMS transport time was measured as the amount of time between the first medical contact with the patient and their arrival at a designated STEMI receiving center. Transport time is measured in minutes on a continuous scale. For the purpose of statistical analysis all of the dichotomous variables were transformed to a 0 or a 1, a requirement of nominal data for regression analysis.

Covariates. The study collected and analyzed a limited amount of demographic data for use as covariates: patient age, gender, prior history of coronary artery disease, and history of coronary artery bypass grafts. Patient age was measured in years on a continuous scale. Gender was measured as either male or female on a dichotomous scale. Prior history of coronary artery disease was measured as either yes or no on a dichotomous scale. History of coronary artery bypass grafts was measured as either yes or no on a dichotomous scale.

Protection of human subjects

Institutional review board (IRB) approval from Virginia Commonwealth University (VCU) was obtained. Due to the nature of the data collection process this study was classified as exempt. The UHS facilities required approval from their individual facility administration teams prior to data collection. Because this study was a retrospective analysis of secondary data, it was not necessary to recruit human subjects. All data used in this study was retrospective and readily available in the STEMI databases at each facility. In order to further protect patient confidentiality no identifiable patient information was collected from these databases.

Data collection

Upon IRB approval, each of the facilities' chest pain coordinators were contacted directly regarding the possibility of collecting data from their facility. The facilities required approval from their individual administrative teams. Once the approvals were obtained, the necessary data was made available in a secure folder on the hospital's shared server. All data was collected in person directly from the secure folder on the server and transferred directly into a password-protected Excel file on a secure laptop. No raw data was shared via unsecure e-mail or any other digital means of communication. Once extracted, the data remained on the secure laptop computer for which only the lead researcher had access. The document itself, as well as the laptop, were password protected and only the lead researcher had the password.

Data analysis

Data cleaning. The initial data collection yielded a total of 2,240 cases. After the data was collected it was inputted directly into a password protected Microsoft Excel worksheet for data cleaning and application of the exclusion criteria. A total of 821 cases were excluded due to the STEMI activation being canceled. A total of 341 cases were excluded due to no acute occlusions found on the angiogram. A total of 106 cases were excluded due to the patient being sent for emergent CABG prior to PCI, an additional 79 cases were excluded due to the patient expiring prior to PCI. A total of 68 cases were excluded due to the patient being considered "in house" STEMIs and another 63 cases were excluded due to the STEMI only being called after multiple ECGs were performed. A total of 115 cases were excluded due to missing values. The final sample consisted of 647 cases. A complete breakdown of the sample sizes by research question is found in

Table 2. The final sample data was uploaded into the Statistical Package for the Social Sciences (SPSS) version 23 software program for subsequent analysis.

Table 2. Breakdown of Sample Sizes by Research Question.

Research question (RQ)	Sample size	Sample assessment
RQ1	618	After removal of outliers
RQ2	422	Initial sample of 647 stratified by mode of arrival. Only EMS cases chosen. Resulting EMS sample assessed for outliers.
RQ3	237, 113, 153, 130	Initial sample of 647 stratified by facility. Each facility sample assessed for outliers.
RQ4	157, 97, 95, 74	Initial sample of 647 stratified by facility. Each facility sample further stratified by mode of arrival. Only EMS cases chosen. Each facility EMS sample assessed for outliers.

Statistical analyses. All statistical analyses for the study were conducted using the SPSS version 26 software program. This study used multiple analyses in order to develop the statistical models necessary to satisfy the four research questions. The analyses were conducted using an alpha of < 0.05 and a power of 0.80. With 13 predictors and an effect size of 0.30, 72 cases were required.

Analysis of Predictors of Door to Balloon time (RQ1). Research question 1 (RQ1) asked the following: Which process factor(s) has/have a statistically significant impact on the door to balloon time in patients presenting with a STEMI, while controlling for the factors of age, gender and history of coronary artery disease, and history of coronary artery bypass grafts?

The purpose of the initial analysis was to establish a model of the predictors for door to balloon times and used the entire study sample (N= 618) after assessing for and removing outliers. The dependent variable was the D2B time and all independent variables and covariates were used with the exception of EMS transport time. The scatter plots and residual plots were examined for normality and linearity. A multiple regression analysis was conducted using stepwise insertion of the independent variables. The resulting series of statistical models contain the independent variables that together are the best predictors of the door to balloon times, thereby providing evidence relevant to RQ1. Finally, the standardized and unstandardized Beta values as well as part and particle correlations were analyzed in order to establish the magnitude of the impact of the predictors on Door to balloon times.

Analysis of Predictors of First Medical Contact to Balloon time (RQ2). Research question 2 (RQ2) asked the following: Which process factor(s) has/have a statistically significant impact on the first medical contact to balloon time in patients presenting, via EMS, with a STEMI, while controlling for the factors of age, gender and history of coronary artery disease, and history of coronary artery bypass grafts?

The purpose of this analysis was to establish a model of predictors of first medical contact to balloon time. It was conducted using the initial study sample of 647 cases stratified by mode of arrival. Only the cases transported by EMS were compiled. The stratified sample as assessed for outliers and they were removed for a final sample size of 422. The dependent variable was FMC time. This analysis was performed using all of the independent variables and covariates with the exception of the mode of arrival variable. The scatter plots and residual plots were examined for normality and linearity. A multiple regression analysis was conducted using stepwise insertion of the independent variables. The resulting series of statistical models contain the independent variables that together are the best predictors of the FMC, thereby providing evidence relevant to RQ2. Finally, the standardized and unstandardized Beta values were analyzed in order to establish the magnitude of the impact of the predictors on First medical contact to balloon times.

Analysis Predictors of D2B times at Individual facilities (RQ3). The third research question (RQ3) asked the following: Which process factor(s) has/have a statistically significant impact on the door to balloon time in patients presenting with a STEMI, at the level of each individual facility, while controlling for the factors of age, gender and history of coronary artery disease, and history of coronary artery bypass grafts?

The purpose of the this set of analyses was to establish a model of predictors of door to balloon time specific to individual facilities. These analyses utilized the initial study sample of 647 cases. This sample was stratified by individual facility resulting in facility specific samples. Outliers were assessed for and removed from each facility sample resulting in individual facility sample sizes of; Facility A (N= 237), Valley (N= 113), Summerlin (N= 153) and Facility D (N= 130). The scatter plots and residual plots were examined for normality and linearity. Multiple regression analyses were conducted using stepwise insertion of the independent variables. These analyses were run using D2B as the dependent variable and all of the independent variables and covariates, with the exception of the EMS transport time variable. This analysis was repeated for each facility. These analyses provided a series of statistical models for each facility that outline the independent variables that are the best predictors of D2B time. The results of these analyses satisfy RQ3. Finally, the standardized and unstandardized Beta values were analyzed in order to establish the magnitude of the impact of the predictors on Door to balloon times at the individual facility level.

Analysis of Predictors of FMC to Balloon times at individual facilities (RQ4). The final research question (RQ4) asked: Which process factor(s) has/have a statistically significant impact on the first medical contact to balloon time in patients presenting, via EMS, with a STEMI, at the level of each individual facility, while controlling for the factors of age, gender and history of coronary artery disease, and history of coronary artery bypass grafts?

The purpose of the final series of analyses was to establish predictors of first medical contact to balloon time specific to the individual facilities. These analyses were conducted using the initial study sample of 647 stratified by mode of arrival and individual facility. Only the cases transported by EMS were selected for the facilities. Outliers were assessed for and removed from each facility sample resulting in the following sample sizes; Facility A (N= 157), Valley (N=97), Summerlin (N= 95) and Facility D (N= 74). The scatter plots and residual plots were examined for normality and linearity. Multiple regression analyses were conducted using multiple stepwise insertion of the independent variables. This analysis was conducted using FMC as the dependent variable and all of the independent variables and covariates with the exception of the mode of arrival variable. The results of these analyses provide individual facility-based models of the best predictors for FMC times. These results satisfy RQ4. Finally, the standardized and unstandardized Beta values were analyzed in order to establish the magnitude of the impact of the predictors on First medical contact to balloon times at the individual facility level.

Summary

The purpose of this study was to explore and analyze the process factors potentially impacting the reperfusion times in patients presenting with a STEMI and to identify which process factors are most statistically significant. Specifically, this study focused on determining which factor or combination of process factors have the greatest impact on door to balloon time as well as first medical contact to balloon time. Factors such as mode of arrival, EMS transport time, pre-hospital STEMI activation, triage time, cath lab team availability, cardiologist arrival time, and the presence of confounding factors will be analyzed. This analysis was conducted using retrospective secondary data previously collected in the STEMI databases of the four participating STEMI receiving centers in the greater Las Vegas area.

This chapter outlined the methodology of this study. Research design and sampling strategies were described. Dependent and independent variables as well as covariates were defined. Finally, data collection, data cleaning and subsequent statistical analyses were all specified. Chapter four will provide the results of all of the statistical analyses. Chapter five will include discussion and analysis of the results and provide an examination of the implications for individual facility STEMI programs. Finally, Chapter five will discuss the limitations of the study and outline future research opportunities on this topic.

CHAPTER 4: RESULTS

Chapter one established the emergent nature of a STEMI and the importance of the STEMI treatment process. Chapter one also defined the aims and research questions that guided this study. The second chapter reviewed significant literature with regards to the process factors involved with the identification and treatment of a STEMI as well as detailing the theoretical framework used in this study. Chapter three defined the research design and methodology as well as describing the study setting, sampling method and variables used in the study. Finally, the procedures used to extract the data and subsequent statistical analyses are also addressed.

This chapter provides a brief overview of the data preparation procedures as well as reporting of the descriptive statistics of the complete sample and the individual facility samples. The statistical analyses used are described, and the results and subsequent statistical models reported.

Statistical Analyses

Predictors of Door to Balloon Time (RQ1). A multiple linear regression analysis was conducted using the entire sample and Door to balloon time as the dependent variable. The following predictors were used: Mode of arrival, Regular or off hours, Pre-hospital ECG, Pre-hospital STEMI activation, Door to triage, Door to ECG, Door to 1st MD, Cardiologist arrival, Cath lab response time, Lifesaving measures, Critical diagnostic exams, and Anatomical variances. The covariates of age, gender, history of CAD, and history of CABG were controlled. A stepwise insertion method was used for the predictors.

Patients (N = 618) were between the ages of 28 and 89 years old with a mean age of 62.27 (SD ± 11.88). The frequencies and percentages of the sample descriptive statistics are found in Table 3. A significant percentage of the sample patients were male (74.1%). A majority of the sample had no previous documented history of coronary artery disease (79.6%) nor had undergone previous coronary artery bypass surgery (97.9%).

Table 3. Descriptive Statistics of Cases in the RQ1 Analysis.

Variable	Mean	SD	Frequency	Percentage
Age:	62.27	11.88		
Gender:			458	74.1%
Male			160	25.9%
Female				
History of coronary artery disease:				
No			492	79.6%
Yes			126	20.4%
History of CABG:				
No			605	97.9%
Yes			13	2.1%

The dichotomous process factor variables are reported as the frequency and percentage and are found in Table 4. The variables day of the week and time of day were combined and recoded as the variable regular hours or off hours. Over half of the patients (N = 618) presented during off hours (56.3%). Most patients presented to the hospital via

EMS (67.2%) and underwent a prehospital ECG (66.2%). This allowed for prehospital STEMI activation just over half of the time (51.3%). A very minimal number of patients required lifesaving measures (8.6%) or critical diagnostic exams (3.6%) prior to PTCA. Just over one percent of patients had anatomical variances that delayed treatment of their condition. Finally, an overwhelming majority of patients had femoral artery access (96.8%) for their procedures.

Table 4. Description of Nominal Process Factors in RQ1 Analysis.

Variable	Frequency	Percentage
Regular vs. off hours		
Regular	270	43.7%
Off	348	56.3%
Mode of arrival		
EMS	415	67.2%
Civilian	203	32.8%
Prehospital ECG		
Yes	409	66.2%
No	209	33.8%
Prehospital STEMI		
activation	317	51.3%
Yes	301	48.7%
No		
Lifesaving measures		
Yes	53	8.6%
No	565	91.4%
Critical diagnostic exams		
Yes	22	3.6%
No	596	94.4%
Anatomical variances		
Yes	9	3.6%
No	609	96.4%
Route of arterial access		
Femoral	598	96.8%
Radial	20	3.2%

The continuous variables are reported as the mean and standard deviation. The mean Door to triage time was 4.19 minutes (SD± 5.95). The mean Door to ECG time was

4.96 minutes (SD± 4.95). The mean Door to first physician contact time was 5.82 minutes (SD± 6.66). The mean Cardiologist arrival time was 34.59 minutes (SD± 15.22). The mean Cath lab team arrival time was 21.61 minutes (SD± 15.36). The dependent variable of this analysis was Door to balloon time (D2B). D2B is reported as a mean and standard deviation. The mean Door to balloon time is 64.48 minutes (SD± 18.43).

The standardized residuals were plotted on a scatterplot and assessed for normality and homoscedasticity. The standardized residuals were plotted on a histogram and assessed for skewness. The histogram was mildly right skewed with a skewness statistic of 1.27 and SE of .098. The histogram is found in Figure 5. Mahalanobis distances were calculated and assessed. A total of 29 cases were found to be significant outliers. After further review it was determined that these cases should be excluded in order to improve the normality and homoscedasticity of the sample. This resulted in the revised sample size of 618. The scatterplot is found in Figure 6.

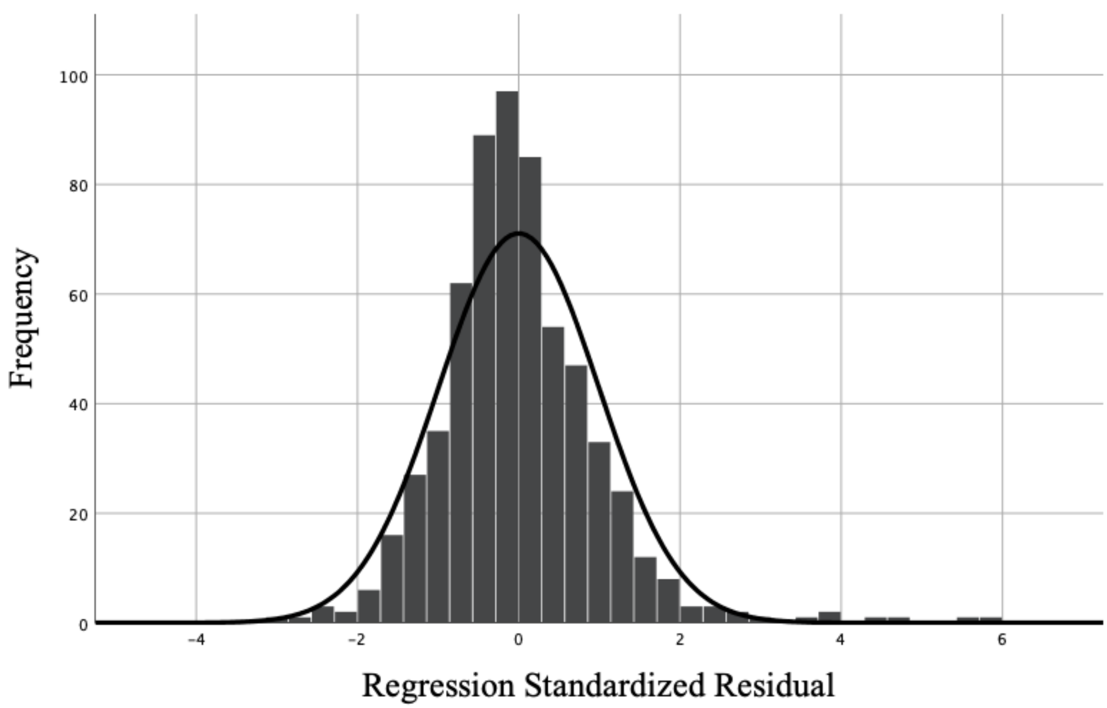

Figure 5. Standardized Residuals Histogram for RQ1 Analysis.

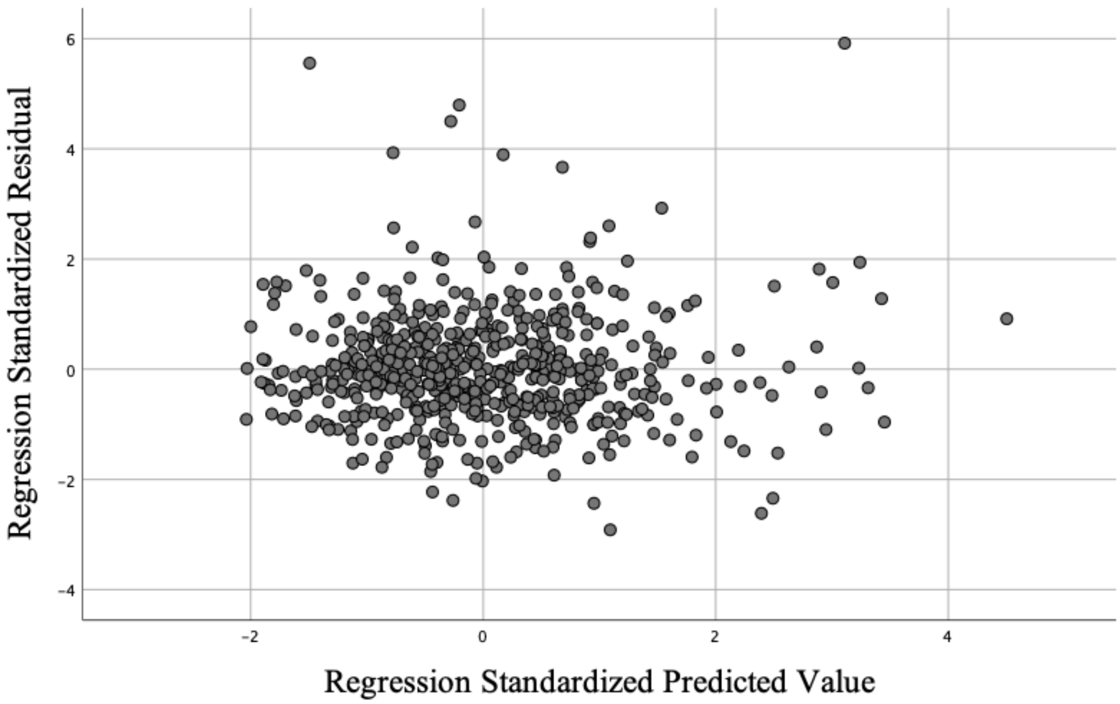

Figure 6. Standardized Residual Scatterplot for RQ1 Analysis.

The regression analysis yielded eight separate models of predictors; the complete model summary is found in Table 5. Model 1 was restricted to the covariates in order to control for them in subsequent models and resulted in an R^2 of .017. This covariate model was not found to be significant. Model 2 inserted the predictor Prehospital STEMI activation and resulted in a significant change in the R^2 at .169. Model 3 added the predictor Cardiologist arrival time and resulted in a change to the R^2 of .115. Model 4 added the predictor Lifesaving measures resulting in an increase of the R^2 by .055. Model 5 added the predictor Door to ECG time resulting in an addition change in the R^2 of .043. Model 6 added the predictor Regular versus off hours resulting in a change in the R^2 of .017. Finally, model 7 added the predictor Critical diagnostic exams resulting in a change in the R^2 of .012. Subsequently, while model 8 was statistically significant it added very little to the explained variance of model 7. From a practical aspect model 7 is the most useful model. Model 8 accounts for less than 1% of the explained variance in Door to balloon times. The predictors Door to triage time, Mode of arrival, Prehospital ECG, Anatomical variances and Route of access did not meet the stepwise insertion criteria and, therefore, were excluded from the models.

Table 5. Summary of RQ1 Regression Models.

Model	Variable added	R^2	Change in the R^2	F statistic	p-value
Model 1	Covariates	.017	.017	2.72	.029
Model 2	Prehospital STEMI activation	.187	.169	28.11	<.001
Model 3	Cardiologist arrival time	.301	.115	43.93	<.001
Model 4	Lifesaving measures	.356	.055	48.16	<.001
Model 5	Door to ECG time	.399	.043	50.45	<.001
Model 6	Regular vs. off hours	.416	.017	48.10	<.001
Model 7	Critical diagnostic exams	.428	.012	45.42	<.001
Model 8	Door to first MD time	.435	.007	42.38	<.001

The coefficients of the models are found in Table 6. The first model was restricted to the covariates and was discussed previously. The inclusion of the predictor Prehospital STEMI activation in the second model had a significant impact on the Beta and partial correlations of the covariates from model 1. The third model added the predictor Cardiologist arrival time. While the addition of this predictor impacted the coefficients of the previous model, the impact was minimal. The fourth model added the predictor

Lifesaving measures. This predictor decreased the coefficients of the previous predictors. The fifth model introduced the predictor Door to ECG time with minimal impact on the previous predictors' coefficients. The sixth and seventh models added the predictors Regular versus off hours and Critical diagnostic exams. Neither of these predictors were significant and had very little impact on the coefficients.

Table 6. Coefficient Values of the RQ1 Regression Models.

Model	B	Beta	Zero-Order	Partial	Part
Model 1:					
Age	.127	.082	.100	.079	.079
Gender	-2.946	-.070	-.085	-.068	-.067
HX of CAD	.289	.006	.021	.006	.006
Hx of CABG	6.941	.054	.057	.052	.052
Model 2:					
Age	.166	.107	.100	.114	.103
Gender	-2.241	-.053	-.085	-.057	-.051
HX of CAD	.886	.019	.021	.020	.018
Hx of CABG	5.421	.042	.057	.045	.040
Prehospital STEMI Activation*	-15.209	-.413	-.408	-.415	-.412
Model 3:					
Age	.147	.095	.100	.108	.091
Gender	-2.000	-.048	-.085	-.055	-.046
HX of CAD	1.064	.023	.021	.026	.022
Hx of CABG	1.965	.015	.057	.017	.015
Prehospital STEMI Activation*	-14.934	-.405	-.408	-.435	-.404
Cardiologist arrival time*	.412	.340	.356	.375	.339
Model 4:					
Age	.150	.096	.100	.115	.093
Gender	-2.054	-.049	-.085	-.058	-.047
HX of CAD	1.521	.033	.021	.039	.031
Hx of CABG	3.185	.025	.057	.029	.024

Model	B	Beta	Zero-Order	Partial	Part
Prehospital STEMI Activation*	-14.542	-.395	-.408	-.440	-.393
Cardiologist arrival time*	.385	.318	.356	.366	.315
Lifesaving Measures*	15.482	.235	.279	.280	.234
Model 5:					
Age	.121	.078	.100	.096	.075
Gender	-1.817	-.043	-.085	-.053	-.042
HX of CAD	2.270	.050	.021	.060	.047
Hx of CABG	3.333	.026	.057	.032	.025
Prehospital STEMI Activation*	-12.378	-.336	-.408	-.383	-.322
Cardiologist arrival time*	.383	.316	.356	.375	.313
Lifesaving Measures*	14.742	.224	.279	.275	.222
Door to ECG time*	.806	.217	.334	.257	.206
Model 6:					
Age	.122	.078	.100	.098	.075
Gender	-1.764	-.042	-.085	-.053	-.040
HX of CAD	2.175	.048	.021	.058	.045
Hx of CABG	1.798	.014	.057	.017	.013
Prehospital STEMI Activation*	-12.297	-.334	-.408	-.386	-.320
Cardiologist arrival time*	.350	.289	.356	.345	.281
Lifesaving Measures*	14.315	.218	.279	.271	.215
Door to ECG time*	.821	.221	.334	.265	.210
Regular vs off hours*	-5.026	-.135	-.215	-.170	-.132
Model 7:					
Age	.120	.077	.100	.097	.074
Gender	-1.715	-.041	-.085	-.052	-.039
HX of CAD	2.605	.057	.021	.070	.053
Hx of CABG	1.726	.013	.057	.017	.013
Prehospital STEMI Activation*	-12.086	-.328	-.408	-.383	-.314
Cardiologist arrival time*	.337	.278	.356	.335	.269
Lifesaving Measures*	9.435	.143	.279	.154	.118
Door to ECG time*	.819	.220	.334	.267	.210

Model	B	Beta	Zero-Order	Partial	Part
Regular vs off hours*	-4.775	-.129	-.215	-.163	-.125
Critical Diagnostic exams*	13.442	.135	.302	.144	.110
Model 8:					
Age	.118	.076	.100	.096	.073
Gender	-1.801	-.043	-.085	-.055	-.041
HX of CAD	2.559	.056	.021	.069	.052
Hx of CABG	1.446	.011	.057	.014	.011
Prehospital STEMI Activation*	-11.074	-.301	-.408	-.342	-.274
Cardiologist arrival time*	.331	.273	.356	.331	.264
Lifesaving Measures*	9.433	.143	.279	.155	.118
Door to ECG time*	.691	.186	.334	.214	.165
Regular vs off hours*	-4.963	-.134	-.215	-.170	-.129
Critical Diagnostic exams*	14.269	.144	.302	.153	.116
Door to 1st MD time	.266	.096	.287	.109	.082

* Denotes a p-value < 0.005

The purpose of this analysis was to provide evidence relevant to the first research question: Which process factor(s) has a statistically significant impact on the door to balloon time in patients presenting with a STEMI, while controlling for the factors of age, gender and history of coronary artery disease, and history of coronary artery bypass grafts? While this question is answered by the final statistical model, from a practical standpoint the final model adds less than 1% to the explained variance of Door to balloon time. The 7th model accounts for over 42% of the variance in Door to balloon time and is the best and most practical model of the predictors that have significant impact on Door to balloon times.

Predictors of First Medical Contact to Balloon Time (RQ2). In order to analyze First medical contact to balloon time the complete data sample was stratified by the predictor Mode of arrival, and only the patients presenting via EMS were used in this analysis. Patients (N = 422) were between the ages of 28 and 89 years old; the mean age was 63.05 (SD ± 11.61). The frequencies and percentages of the sample descriptive statistics are found in Table 7. A significant percentage of the stratified sample patients was male (70.9%). A majority of the sample had no previous documented history of coronary artery disease (78%) nor had undergone previous coronary artery bypass surgery (98.3%).

Table 7. Descriptive Statistics of Patients Presenting via EMS in RQ2.

Variable	Mean	SD	Frequency	Percentage
Age:	63.05	11.61		
Gender:			299	70.9%
Male			123	29.1%
Female				
History of coronary artery disease:				
No			329	78%
Yes			93	22%
History of				
CABG:			415	98.3%
No			7	1.7%
Yes				

The dichotomous process factor variables are reported as the frequency and percentage (see Table 8). The variables day of the week and time of day were combined and recoded as the variable regular hours or off hours. Over half of the patients presented during off hours (58.5%). Most patients underwent a prehospital ECG (98.6%). This allowed for prehospital STEMI activation just over 75% of the time (76.1%). A very minimal number of patients required lifesaving measures (12.1%) or critical diagnostic exams (5.2%) prior to PTCA. Over three and a half percent of patients had anatomical variances that delayed the treatment of their condition. Finally, an overwhelming majority of patients had femoral artery access (96%) for their procedures.

Table 8. Description of Nominal Process Factors in RQ2 Analysis.

Variable	Frequency	Percentage
Regular vs. off hours		
Regular	175	41.5%
Off	247	58.5%
Prehospital ECG		
Yes	416	98.6%
No	6	1.4%
Prehospital STEMI		
activation	321	76.1%
Yes	101	23.9%
No		
Lifesaving measures		
Yes	51	12.1%
No	371	87.9%
Critical diagnostic exams		
Yes	22	5.2%
No	400	94.8%
Anatomical variances		
Yes	15	3.6%
No	407	96.4%
Route of arterial access		
Femoral	405	96%
Radial	17	4%

The continuous variables are reported as the mean and standard deviation. The mean Door to triage time was 3.92 minutes (SD± 5.96). The mean Door to ECG time was 4.56 minutes (SD± 4.77). The mean Door to first physician contact time was 4.13 minutes (SD± 5.74). The mean Cardiologist arrival time was 34.35 minutes (SD± 15.77). The mean Cath lab team arrival time was 21.35 minutes (SD± 15.86). The mean EMS transport time was 26.9 minutes (SD± 12.54). The dependent variable of this analysis was First medical contact to balloon time (FMC). FMC time is reported as a mean and standard deviation. The mean First medical contact to balloon time was 88.69 minutes (SD± 22.83).

A multiple linear regression analysis was conducted using the stratified sample. First medical contact to balloon time was used as the dependent variable as well as the following predictors; Regular or off hours, EMS transport time, Pre-hospital ECG, Pre-hospital STEMI activation, Door to triage, door to ECG, Door to 1st MD, Cardiologist arrival, cath lab response, Lifesaving measures, Critical diagnostic exams, and anatomical variances. The covariates of age, gender, history of CAD, and history of CABG were controlled. A stepwise insertion method was used for the predictors.

The standardized residuals were plotted in a scatterplot and assessed for normality and homoscedasticity. The standardized residuals were plotted on a histogram and assessed for skewness. The histogram was mildly right skewed with a skewness statistic of 1.39 and SE of .119. The histogram is found in Figure 7. Mahalanobis distances were calculated and assessed. A total of 11 cases were found to be significant outliers. After further review it was determined that these cases should be excluded in order to improve the normality and homoscedasticity of the sample. This resulted in a revised sample size of 422. The scatterplot is illustrated in Figure 8.

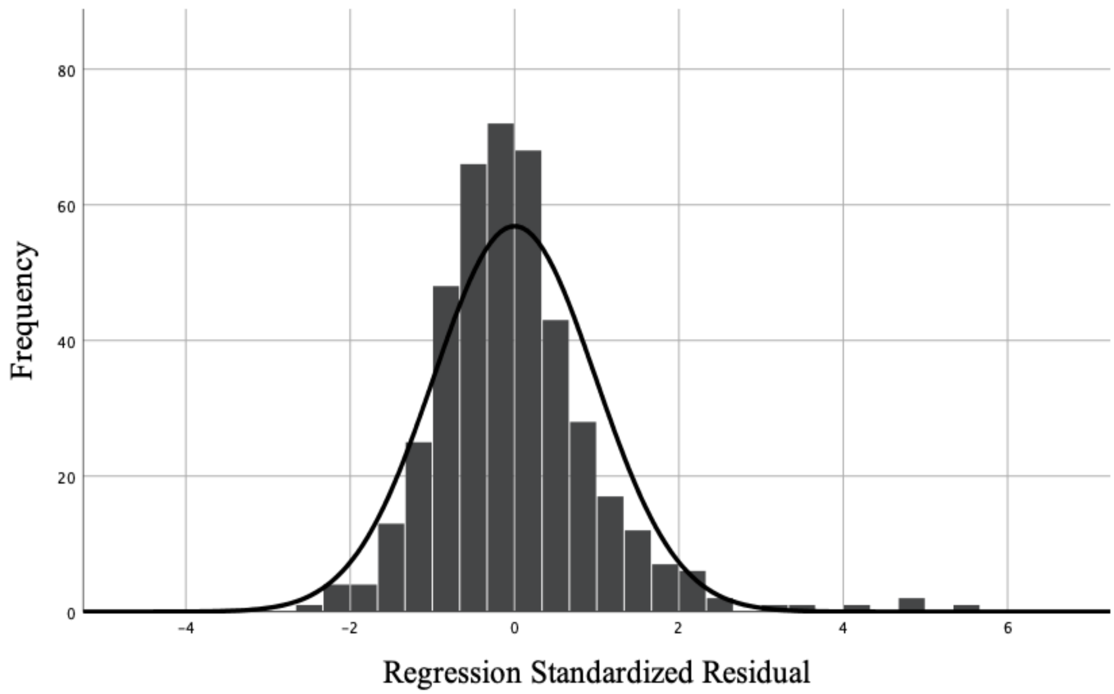

Figure 7. Standardized Residual Histogram for RQ2 Analysis.

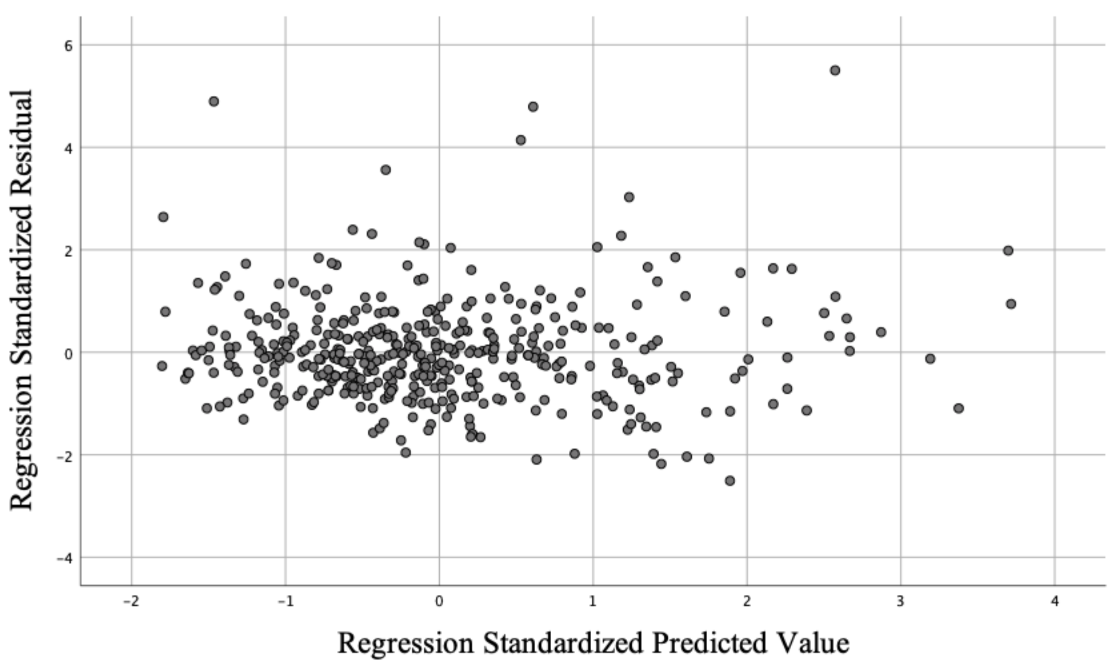

Figure 8. Standardized Residual Scatterplot for RQ2 Analysis.

This analysis yielded eight separate models of the predictors. Model 1 was restricted to the covariates in order to control for them in subsequent models and resulted in and R^2 of 0.058. A majority of the significance of the covariate model is due to the Beta coefficients of the variables Age and Gender. A list of the covariates and their coefficients and correlations are found in Table 9. While the covariate model was found to be significant this is likely due to the large sample size. The complete model summary is found in Table 10.

Table 9. Coefficients of the Covariates of the RQ2 Analysis.

Predictor	Beta	Standard Error	Simple correlations	Partial correlations
Age	.180	0.096	.205	.177
Gender	.132	2.457	.159	.131
Hx of CAD	.017	2.749	.021	.016
Hx of CABG	.009	8.775	.026	.009

Model 2 inserted the predictor EMS transport time and resulted in an R^2 change of .239. Model 3 added the predictor Prehospital STEMI activation resulting in an increase of the R^2 by .121. Model 4 added the predictor Cardiologist arrival time and resulted in an R^2 change of .080. Model 5 added the predictor Lifesaving measures and resulted in an R^2 change of .051. Model 6 added the predictor Door to ECG time resulting in an increase of the R^2 by .023. Model 7 added the predictor Regular vs. off hours and resulted in an R^2 change of .012. The final model added the predictor Critical diagnostic exams and resulted in an increase to the R^2 of .11. The predictors Door to triage time, Door to first MD time, Cath lab team arrival time, Prehospital ECG, Anatomical variances and Route of access did not meet the stepwise insertion criteria and, therefore, were excluded from the models.

Table 10. Summary of RQ2 Regression Models.

Model	Variable added	R^2	Change in the R^2	F statistic	p-value
Model 1	Covariates	.058	.058	6.47	<.001
Model 2	EMS transport time	.297	.239	35.17	<.001
Model 3	Prehospital STEMI activation	.418	.121	49.67	<.001
Model 4	Cardiologist arrival time	.498	.080	58.61	<.001
Model 5	Lifesaving measures	.549	.051	62.77	<.001
Model 6	Door to ECG time	.572	.023	61.17	<.001
Model 7	Regular vs. off hours	.584	.012	57.64	<.001
Model 8	Critical diagnostic exams	.595	.011	54.65	<.001

The regression coefficients for all eight models were assessed and are found in Table 11. The introduction of the predictor EMS transport time in the second model decreased most of the beta, part and partial coefficients of the covariates. Subsequently, the introduction of Prehospital STEMI activation in model three had minimal impact on the coefficients. The introduction of Cardiologist arrival time in the fourth model decreased the coefficients of both previous predictors while increasing and decreasing those of the covariates. The introduction of Lifesaving measures in the fifth model increased the coefficients of most of the previous predictors. The predictor Door to ECG time was introduced in the sixth model. This model again saw some of the beta coefficients of predictors increase while other decreased. The final two models added the predictors Regular versus off hours and Critical diagnostic exams. Both models saw significant fluctuations of the coefficients.

Table 11. Coefficient Values of the RQ2 Regression Models.

Models	B	Beta	Zero-order	Partial	Part
Model 1:					
Age	.353	.180	.205	.177	.174
Gender	6.634	.132	.159	.131	.128
HX of CAD	.913	.017	.021	.016	.016
Hx of CABG	1.638	.009	.026	.009	.009
Model 2:					
Age	.227	.115	.205	.131	.111
Gender	5.089	.101	.159	.116	.098
HX of CAD	1.349	.025	.021	.028	.023
Hx of CABG	-1.644	-.009	.026	-.011	-.009
EMS transport Time*	.901	.495	.519	.503	.489
Model 3:					
Age	.231	.118	.205	.147	.113
Gender	2.572	.051	.159	.064	.049
HX of CAD	.555	.010	.021	.013	.010
Hx of CABG	.561	.003	.026	.004	.003
EMS transport Time*	.866	.475	.519	.523	.469
Prehospital STEMI Activation*	-18.813	-.352	-.393	-.415	-.348
Model 4:					
Age	.224	.114	.205	.153	.110
Gender	2.091	.042	.159	.056	.040
HX of CAD	.235	.004	.021	.006	.004
Hx of CABG	-1.314	-.007	.026	-.010	-.007
EMS transport Time*	.799	.439	.519	.518	.429
Prehospital STEMI Activation*	-18.466	-.346	-.393	-.434	-.341
Cardiologist arrival time*	.414	.286	.364	.370	.282
Model 5:					
Age	.247	.126	.205	.177	.121
Gender	2.465	.049	.159	.070	.047
HX of CAD	1.167	.021	.021	.030	.020

Models	B	Beta	Zero-order	Partial	Part
EMS transport Time*	.827	.454	.519	.551	.443
Prehospital STEMI Activation*	-15.653	-.293	-.393	-.387	-.282
Cardiologist arrival time*	.381	.263	.364	.360	.259
Lifesaving Measures*	16.382	.234	.289	.319	.226
Model 6:					
Age	.228	.116	.205	.168	.111
Gender	1.986	.040	.159	.058	.038
HX of CAD	1.748	.032	.021	.046	.030
Hx of CABG	-.448	-.003	.026	-.004	-.002
EMS transport Time*	.840	.461	.519	.566	.449
Prehospital STEMI Activation*	-12.807	-.240	-.393	-.317	-.219
Cardiologist arrival time*	.367	.253	.364	.355	.249
Lifesaving Measures*	15.452	.221	.289	.309	.212
Door to ECG time*	.790	.165	.312	.227	.152
Model 7:					
Age	.233	.119	.205	.174	.114
Gender	1.881	.037	.159	.055	.036
HX of CAD	1.608	.029	.021	.043	.028
Hx of CABG	-2.426	-.014	.026	-.020	-.013
EMS transport Time*	.850	.467	.519	.576	.454
Prehospital STEMI Activation*	-12.460	-.233	-.393	-.313	-.212
Cardiologist arrival time*	.321	.222	.364	.309	.210
Lifesaving Measures*	15.220	.218	.289	.308	.209
Door to ECG time*	.847	.177	.312	.244	.163
Regular versus off*	5.290	.114	.177	.166	.109
Model 8:					
Age	.235	.119	.205	.177	.115
Gender	1.830	.036	.159	.055	.035
HX of CAD	2.250	.041	.021	.060	.038
Hx of CABG	-2.829	-.016	.026	-.024	-.015
EMS transport Time*	.864	.475	.519	.586	.461

Models	B	Beta	Zero-order	Partial	Part
Cardiologist arrival time*	.302	.209	.364	.294	.196
Lifesaving Measures*	10.506	.150	.289	.189	.122
Door to ECG time*	.829	.173	.312	.242	.159
Regular versus off*	5.188	.112	.177	.165	.107
Critical Diagnostic exams*	13.222	.129	.287	.161	.104

* Denotes p-value < .005

The purpose of this analysis was to provide evidence relevant to the second research question: Which process factor(s) has a statistically significant impact on the first medical contact to balloon time in patients presenting with a STEMI, while controlling for the factors of age, gender and history of coronary artery disease, and history of coronary artery bypass grafts? This question is answered by the 8th model and final of the FMC analysis. This model accounts for nearly 70% of the variance in First medical contact to balloon time. The predictors of both the D2B models and the FMC model are virtually identical with the exception of EMS transport time which was only analyzed in the EMS models.

Predictors of D2B and FMC Time at the Individual Facility Level (RQ3). This section contains the D2B and FMC analyses at the individual facility level. In order to analyze and generate facility specific statistical models, it was necessary to stratify the initial complete sample (N = 647) by individual facility. The four facilities that provided data were Facility A Hospital, Facility B, Facility C, and Facility D. The following section is organized by facility with the D2B analyses (RQ3) first, followed by the FMC analyses (RQ4).

Facility A D2B analysis. Patients (N = 237) were between the ages of 29 and 89 years old; the mean age was 61.19 (SD ± 11.72). The frequencies and percentages of the sample descriptive statistics are found in Table 12. A significant percentage of the sample patients were male (73.8%). A majority of the sample had no previous documented history of coronary artery disease (77.2%) and a majority had not undergone coronary artery bypass surgery (95.8%).

Table 12. Descriptive Statistics of Cases in the RQ 3 Analysis at Facility A.

Variable	Mean	SD	Frequency	Percentage
Age:	61.19	11.72		
Gender:				
Male			175	73.8%
Female			62	26.2%
History of coronary artery disease:			183	77.2%
No			54	22.8%
Yes				
History of CABG:				
No			227	95.8%
Yes			10	4.2%

The dichotomous process factor variables are reported as the frequency and percentage and are found in Table 13. The variables day of the week and time of day were combined and recoded as the variable regular hours or off hours. Over half of the patients presented during off hours (62%). Most patients presented to the hospital via EMS (66.2%) and underwent a prehospital ECG (65%). This allowed for prehospital STEMI activation just under half of the time (49.8%). A very minimal number of patients required lifesaving measures (8.4%) or critical diagnostic exams (3%) prior to PTCA. Just over five percent of patients had anatomical variances that delayed treatment of their condition (5.1%). Finally, an overwhelming majority of patients had femoral artery access (94.9%) for their procedures.

Table 13. Description of Nominal Process Factors from RQ3 Analysis at Facility A.

Variable	Frequency	Percentage
Regular vs. off hours		
Regular	90	38%
Off	147	62%
Mode of arrival		
EMS	157	66.2%
Civilian	80	33.8%
Prehospital ECG		
Yes	154	65%
No	83	35%
Prehospital STEMI		
activation	118	49.8%
Yes	119	50.2%
No		
Lifesaving measures		
Yes	20	8.4%
No	217	91.6%
Critical diagnostic exams		
Yes	7	3%
No	230	97%
Anatomical variances		
Yes	12	5.1%
No	225	94.9%
Route of arterial access		
Femoral	225	94.9%
Radial	12	5.1%

The continuous variables are reported as the mean and standard deviation. The mean Door to triage time was 2.41 minutes (SD± 4.55). The mean Door to ECG time was 4.29 minutes (SD± 4.94). The mean Door to first physician contact time was 4.10 minutes (SD± 5.22). The mean Cardiologist arrival time was 31.02 minutes (SD± 15.81).

The mean Cath lab team arrival time was 13.65 minutes (SD± 12.55). The dependent variable of this analysis was Door to balloon time (D2B). D2B is reported as a mean and standard deviation. The mean Door to balloon time was 64.26 minutes (SD± 19.59).

A multiple linear regression analysis was conducted using the stratified sample (N = 237) and Door to balloon time as the dependent variable. The following predictors were used: Mode of arrival, Regular or off hours, Pre-hospital ECG, Pre-hospital STEMI activation, Door to triage, door to ECG, Door to 1st MD, Cardiologist arrival, cath lab response, Lifesaving measures, Critical diagnostic exams, and anatomical variances. The covariates of age, gender, history of CAD, and history of CABG were controlled for. A stepwise insertion method was used for the predictors.

The standardized residuals were plotted in a scatterplot and assessed for normality and homoscedasticity. The standardized residuals were also plotted on a histogram and assessed for skewness. The histogram was mildly right skewed with a skewness statistic of 1.49 and SE of .158. The histogram is found in Figure 9. Mahalanobis distances were calculated and assessed. A total of 5 cases were found to be significant outliers. After further review it was determined that these cases should be excluded in order to improve the normality and homoscedasticity of the sample. This resulted in the revised sample size of 237. The scatterplot is illustrated in Figure 10.

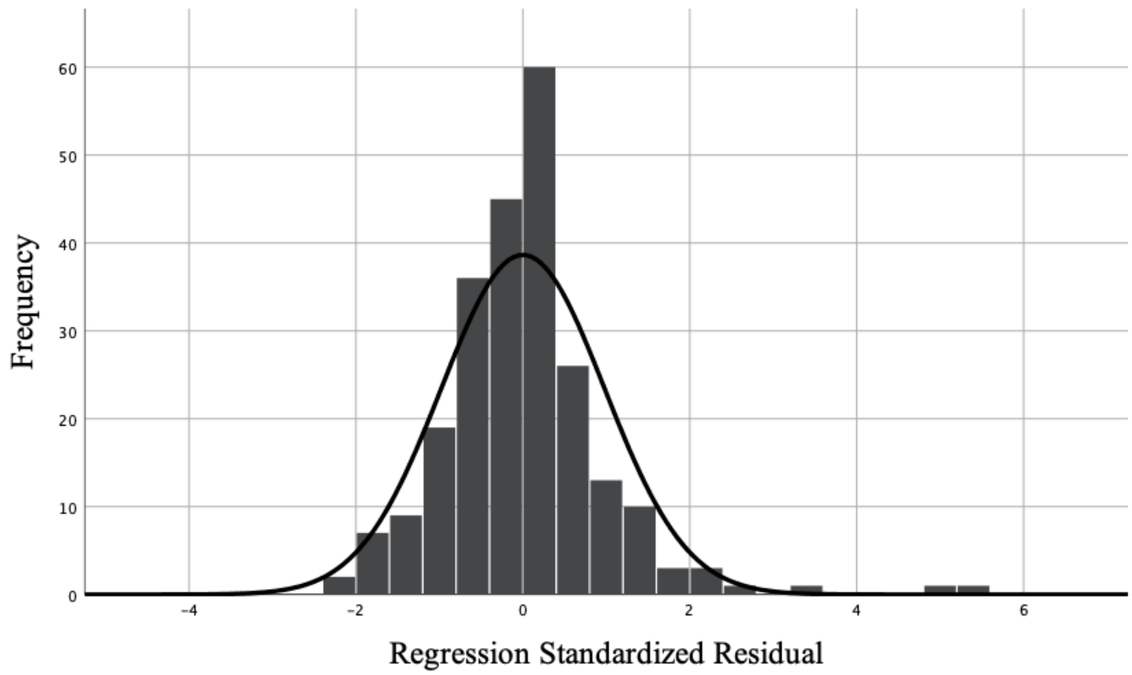

Figure 9. Standardized Residual Histogram of the RQ3 Analysis at Facility A.

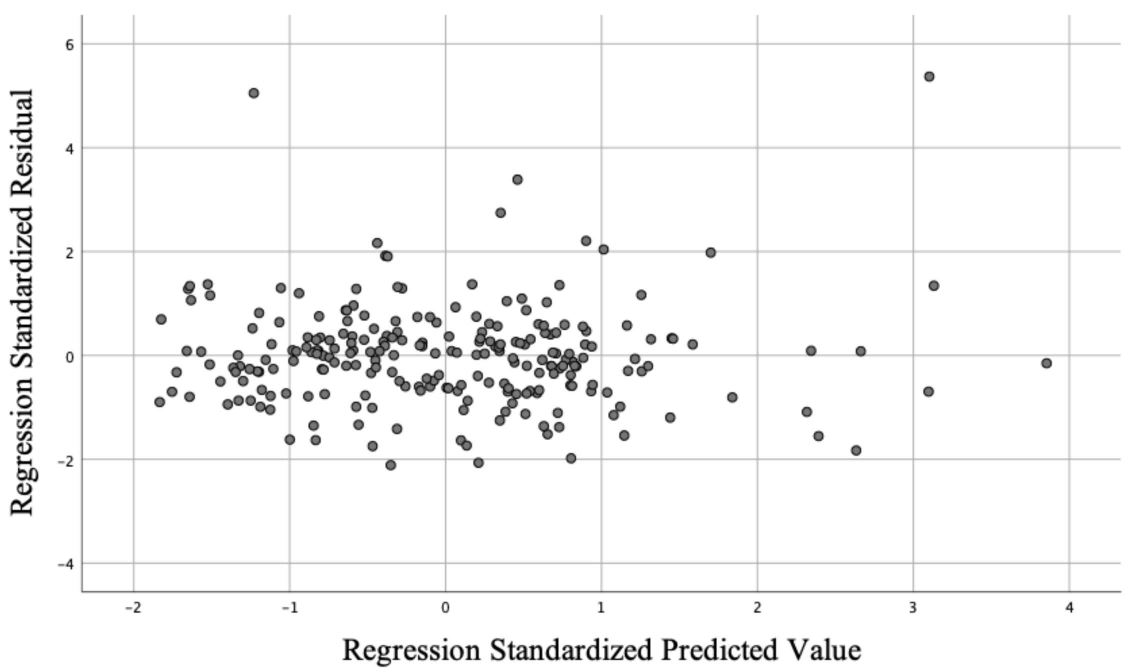

Figure 10. Standardized Residual Scatterplot of the RQ3 Analysis at Facility A.

This analysis yielded seven separate models of the predictors. The complete model summary is found in Table 14. Model 1 was restricted to the covariates in order to control for them in subsequent models and resulted in and R^2 of .052. Model 2 inserted the predictor Prehospital STEMI activation and resulted in an R^2 change of .172. Model 3 included both Prehospital STEMI activation and Cardiologist arrival time and resulted in an R^2 change of .087. Model 4 added the predictor Critical diagnostic exams and resulted in an R^2 change of .045. Model 5 added the predictor Door to ECG time resulting in an R^2 change of .049. Model 6 added the predictor Anatomical variances and resulted in an R^2 change of .019. Finally, model 7 added the predictor Regular vs. off hours resulting in an R^2 change of .016. This regression model was significant with $F(10, 226) = 17.680$ with a p-value < 0.001. The predictors Door to triage time, Mode of arrival, Prehospital ECG Door to ECG, Cath lab team arrival, and Route of access did not meet the stepwise insertion criteria for any of the models.

Table 14. Summary of RQ3 Regression Models at Facility A.

Model	Variable added	R^2	Change in the R^2	F statistic	p-value
Model 1	Covariates	.052	.052	3.17	.015
Model 2	Prehospital STEMI activation	.224	.172	13.31	<.001
Model 3	Cardiologist arrival time	.311	.087	17.28	<.001
Model 4	Critical diagnostic exams	.356	.045	18.06	<.001
Model 5	Door to ECG time	.404	.049	19.34	<.001
Model 6	Anatomical variances	.423	.019	18.48	<.001
Model 7	Regular vs. off hours	.439	.016	17.68	<.001

The regression coefficients for all seven models were assessed and are found in Table 15. The introduction of the predictor Prehospital STEMI activation in the second model had significant impact on the coefficients of nearly all the covariates. Subsequently, the introduction of Cardiologist arrival time in model three decreased both the beta and part coefficients for Prehospital STEMI activation while increasing the partial. The introduction of Critical diagnostic exams in the fourth model decreased the coefficients of both previous predictors. The introduction of Door to ECG time in the fifth model resulted in a mild increased of the coefficients of the previous predictors. The predictors Anatomical variances was introduced in the sixth model. This predictor caused both increases and decreases in the coefficients of the previous predictors. Finally, the predictor Regular versus off hours was introduced in the final model with minimal impact on the coefficients of the previous predictors.

Table 15. Coefficient Values of the RQ3 Regression Models at Facility A.

Models	B	Beta	Zero-order	Partial	Part
Model 1:					
Age	.274	.164	.181	.159	.157
Gender	-1.790	-.040	-.070	-.039	-.038
HX of CAD	1.339	.029	.081	.027	.026
Hx of CABG	11.999	.123	.138	.116	.114
Model 2:					
Age	.293	.175	.181	.187	.168
Gender	-1.490	-.034	-.070	-.036	-.032
HX of CAD	.662	.014	.081	.015	.013
Hx of CABG	9.087	.093	.138	.097	.086
Prehospital STEMI Activation*	-16.273	-.416	-.422	-.426	-.415
Model 3:					
Age	.283	.169	.181	.191	.162
Gender	-.644	-.014	-.070	-.016	-.014
HX of CAD	.207	.004	.081	.005	.004
Hx of CABG	8.796	.090	.138	.100	.083

Models	B	Beta	Zero-order	Partial	Part
Prehospital STEMI Activation*	-16.512	-.422	-.422	-.452	-.421
Cardiologist arrival time*	.366	.296	.298	.335	.295
Model 4:					
Age	.244	.146	.181	.171	.139
Gender	-.536	-.012	-.070	-.014	-.011
HX of CAD	1.279	.027	.081	.031	.025
Hx of CABG	8.977	.092	.138	.105	.085
Prehospital STEMI Activation*	-15.786	-.404	-.422	-.446	-.401
Cardiologist arrival time*	.329	.265	.298	.310	.262
Critical Diagnostic exams*	25.093	.217	.295	.255	.212
Model 5:					
Age	.208	.124	.181	.151	.118
Gender	-.414	-.009	-.070	-.011	-.009
HX of CAD	2.585	.055	.081	.064	.050
Hx of CABG	9.373	.096	.138	.114	.089
Prehospital STEMI Activation*	-14.162	-.362	-.422	-.416	-.353
Cardiologist arrival time*	.336	.271	.298	.328	.268
Critical Diagnostic exams*	26.236	.227	.295	.276	.222
Door to ECG time*	.899	.227	.277	.274	.220
Model 6:					
Age	.189	.113	.181	.139	.107
Gender	-.433	-.010	-.070	-.012	-.009
HX of CAD	2.829	.061	.081	.071	.054
Hx of CABG	4.295	.044	.138	.050	.038
Prehospital STEMI Activation*	-14.954	-.383	-.422	-.437	-.369

Models	B	Beta	Zero-order	Partial	Part
Cardiologist arrival time*	.335	.270	.298	.331	.266
Critical Diagnostic exams*	26.741	.232	.295	.285	.226
Door to ECG time*	.908	.229	.277	.281	.222
Anatomical Variances	13.137	.147	.118	.177	.137
Model 7:					
Age	.184	.110	.181	.137	.104
Gender	-.709	-.016	-.070	-.020	-.015
HX of CAD	2.665	.057	.081	.068	.051
Hx of CABG	3.380	.035	.138	.040	.030
Prehospital STEMI Activation*	-14.559	-.372	-.422	-.432	-.358
Cardiologist arrival time*	.304	.245	.298	.302	.238
Critical Diagnostic exams*	25.852	.224	.295	.279	.218
Door to ECG time*	.850	.214	.277	.266	.207
Anatomical Variances*	13.527	.152	.118	.185	.141
Regular vs off hours	-5.289	-.131	-.267	-.167	-.127

* Denotes a p-value < .005

The purpose of this analysis was to provide evidence relevant to the third research question: Which process factor(s) has a statistically significant impact on the door to balloon time in patients presenting with a STEMI, at the level of each individual facility, while controlling for the factors of age, gender and history of coronary artery disease, and history of coronary artery bypass grafts? This question is answered by the 7th and final statistical model. This model accounts for almost 44% of the variance in Door to balloon times at this facility and is the best and most practical model of the predictors that have significant impact on Door to balloon times. This model closely mirrors the overall D2B model. While the predictor Lifesaving measures did not have a significant impact in this analysis, the predictor Anatomical variances was included in the final model. While this predictor only accounted for about 2% of the explained variance the presence of Anatomical variances was found to be statistically significant.

Facility A FMC analysis (RQ4). In order to analyze First medical contact to balloon time, the Facility A sample was subsequently stratified by Mode of arrival, and only the patients presenting via EMS were used in this analysis.

Patients (N = 157) were between the ages of 29 and 87 years old with a mean age of 61.86 (SD ± 11.60). The frequencies and percentages of the sample descriptive statistics are found in Table 16.

Table 16. Descriptive Statistics of EMS Patients from the RQ4 Analysis at Facility A.

Variable	Mean	SD	Frequency	Percentage
Age:	61.86	11.60		
Gender:				
Male			111	70.7%
Female			46	29.3%
History of coronary artery disease:				
No			124	79%
Yes			33	21%
History of CABG:				
No			151	96.2%
Yes			6	3.8%

A significant percentage of the stratified sample patients were male (70.7%). A majority of the sample had no previous documented history of coronary artery disease (79%) nor had undergone previous coronary artery bypass surgery (96.2%).

The dichotomous process factor variables are reported as the frequency and percentage and are found in Table 17. The variables day of the week and time of day were combined and recoded as the variable regular hours or off hours. Over half of the patients presented during off hours (59.2%). All patients underwent a prehospital ECG (100%). This allowed for prehospital STEMI activation just over 75% of the time (75.8%).

Table 17. Description of nominal process factors from the RQ4 analysis at Facility A.

Variable	Frequency	Percentage
Regular vs. off hours		
Regular	64	40.8%
Off	93	59.2%
Prehospital ECG		
Yes	157	100%
No	0	0%
Prehospital STEMI		
activation	119	75.8%
Yes	38	24.2%
No		
Lifesaving measures		
Yes	17	10.8%
No	140	89.2%
Critical diagnostic exams		
Yes	7	4.5%
No	150	95.5%
Anatomical variances		
Yes	11	7%
No	146	93%
Route of arterial access		
Femoral	149	94.9%
Radial	8	5.1%

A very minimal number of patients required lifesaving measures (10.8%) or critical diagnostic exams (4.5%) prior to PTCA. Anatomical variances that delayed treatment were found in a minimal number of patients (7.0%). Finally, an overwhelming majority of patients had femoral artery access (94.9%) for their procedures.

The continuous variables are reported as the mean and standard deviation. The mean Door to triage time was 2.54 minutes (SD± 5.02). The mean Door to ECG time was 3.72 minutes (SD± 2.90). The mean Door to first physician contact time was 2.27 minutes (SD± 3.34). The mean Cardiologist arrival time was 30.89 minutes (SD± 16.26). The mean Cath lab team arrival time was 12.39 minutes (SD± 12.30). The mean EMS transport time was 27.23 minutes (SD± 14.52). The dependent variable of this analysis was First medical contact to balloon time (FMC). FMC time is reported as a mean and standard deviation. The mean First medical contact to balloon time was 86.81 minutes (SD± 22.85).

A multiple linear regression analysis was conducted using the stratified sample. First medical contact to balloon time was used as the dependent variable as well as the following predictors; Regular or off hours, EMS transport time, Pre-hospital ECG, Pre-hospital STEMI activation, Door to triage, door to ECG, Door to 1st MD, Cardiologist arrival, cath lab response, Lifesaving measures, Critical diagnostic exams, and anatomical variances. The covariates of age, gender, history of CAD, and history of CABG were controlled. A stepwise insertion method was used for the predictors.

The standardized residuals were plotted in a scatterplot and assessed for normality and homoscedasticity. The standardized residuals were plotted on a histogram and assessed for skewness. The histogram was significantly positively skewed with a skewness statistic of 2.13 and SE of .194. The histogram is illustrated in Figure 11. Mahalanobis distances were calculated and assessed. A total of 3 cases were found to be significant outliers. After further review it was determined that these cases should be excluded in order to improve the normality and homoscedasticity of the sample. This resulted in the revised sample size of 157. The scatterplot is illustrated in Figure 12.

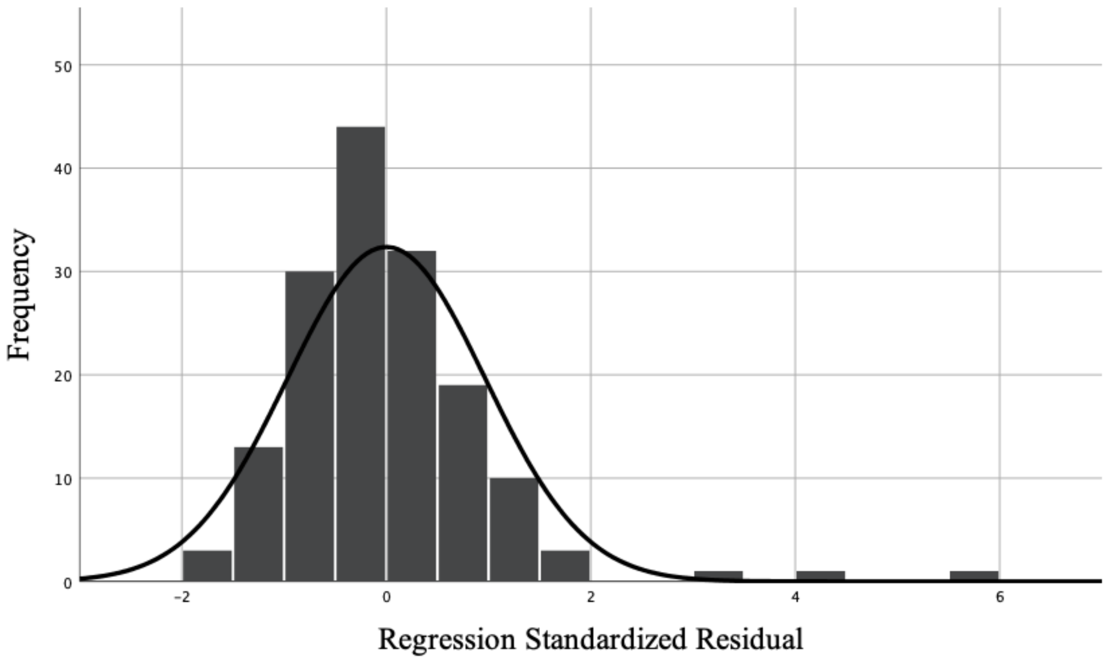

Figure 11. Standardized Residual Histogram of the RQ4 Analysis Facility A.

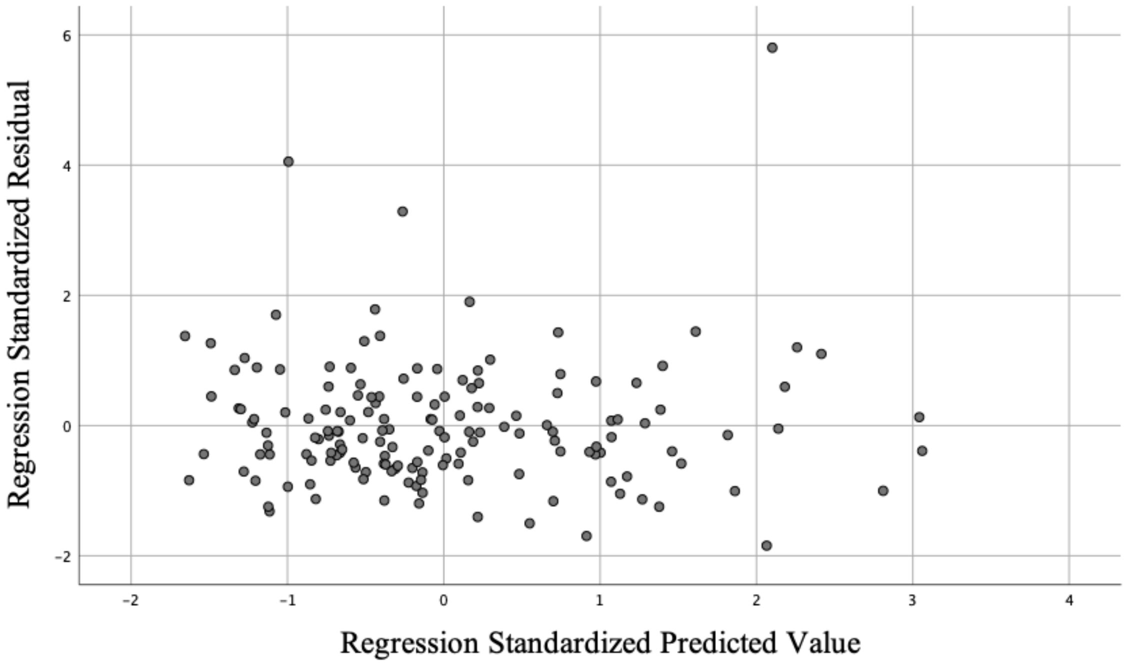

Figure 12. Standardized Residual Scatterplot of the RQ4 Analysis at Facility A.

This analysis yielded seven separate models of the predictors. Model 1 was restricted to the covariates and resulted in and R^2 of .133. A majority of the significance in the covariate model is likely due to the beta coefficients of Age and History of CABG. A list of the covariates and the coefficients are found in Table 18. While the model overall was found to be significant this may be due to the sample size. The complete model summary is found in Table 19.

Table 18. Coefficients of the Covariates of the RQ4 Analysis at Facility A.

Predictor	Beta	Standard Error	Simple correlations	Partial correlations
Age	.277	0.156	.316	.272
Gender	-.108	4.022	-.171	-.108
Hx of CAD	-.081	4.665	-.008	-.078
Hx of CABG	.168	9.803	.156	.163

Model 2 inserted the predictor EMS transport time and resulted in an R^2 change of .231. Model 3 added the predictor Prehospital STEMI activation and resulted in an R^2 change of .070. Model 4 added the predictor Cardiologist arrival time and resulted in an R^2 change of .050. Model 5 added the predictor Lifesaving measures and resulted in an R^2 change of .028. Model 6 added the predictor Cath lab team arrival time and resulted in a minimal R^2 change of .014. Finally, model 7 added the predictor Door to first MD time and again resulted in a minimal R^2 change of .015. This regression model was significant with F (10, 146) = 17.20 with a p-value < 0.001. The predictors Prehospital ECG time, Door to triage time, Door to ECG time, Critical diagnostic exams, Anatomical variances, Regular versus off hours and Route of access did not meet the stepwise insertion criteria and, therefore, were excluded from the models.

Table 19. Summary of RQ4 Regression Models at Facility A.

Model	Variable added	R^2	Change in the R^2	F statistic	p-value
Model 1	Covariates	.133	.133	5.82	<.001
Model 2	EMS transport time	.364	.231	17.27	<.001
Model 3	Prehospital STEMI activation	.434	.070	19.18	<.001
Model 4	Cardiologist arrival time	.484	.050	19.97	<.001
Model 5	Lifesaving measures	.512	.028	19.38	<.001
Model 6	Cath lab team arrival time	.526	.014	18.09	<.001
Model 7	Door to first MD time	.541	.015	17.20	<.001

The regression coefficients for all seven models were assessed and are found in Table 20. The introduction of the predictor EMS transport time in the second model had significant impact on the coefficients of nearly all the covariates. Subsequently, the introduction of Prehospital STEMI activation in model three decreased both the beta and part coefficients for EMS transport time while increase the partial. The introduction of Cardiologist arrival time in the fourth model decreased the coefficients of both previous predictors. The introduction of Lifesaving measures in the fifth model resulted in a mild increased of the coefficients of the previous predictors. Cath lab team arrival time was introduced in the sixth model. This predictor cased both increased and decreases in the coefficients of the previous predictors. However, neither Cath lab arrival time nor the final predictor Door to first MD time had statistically significant coefficients.

Table 20. Coefficient values of the RQ4 regression models at Facility A.

Models	B	Beta	Zero-order	Partial	Part
Model 1:					
Age	.546	.277	.316	.272	.263
Gender	-5.403	-.108	-.171	-.108	-.101
HX of CAD	-4.507	-.081	-.008	-.078	-.073
Hx of CABG	19.956	.168	.156	.163	.154
Model 2:					
Age	.365	.185	.316	.213	.173
Gender	-4.735	-.095	-.171	-.111	-.089
HX of CAD	-1.703	-.030	-.008	-.034	-.027
Hx of CABG	13.151	.111	.156	.125	.101
EMS transport Time*	.778	.494	.550	.516	.481
Model 3:					
Age	.361	.183	.316	.222	.171
Gender	-3.053	-.061	-.171	-.075	-.057
HX of CAD	-1.862	-.033	-.008	-.040	-.030
Hx of CABG	11.720	.099	.156	.118	.090
EMS transport Time*	.739	.470	.550	.517	.455
Prehospital STEMI Activation*	-14.301	-.269	-.342	-.332	-.265

Models	B	Beta	Zero-order	Partial	Part
Model 4:					
Age	.372	.189	.316	.239	.177
Gender	-2.414	-.048	-.171	-.062	-.045
HX of CAD	-1.635	-.029	-.008	-.037	-.026
Hx of CABG	11.311	.095	.156	.120	.087
EMS transport Time*	.674	.428	.550	.494	.409
Prehospital STEMI Activation*	-15.363	-.289	-.342	-.367	-.284
Cardiologist arrival time*	.320	.228	.292	.297	.223
Model 5:					
Age	.360	.183	.316	.237	.171
Gender	-1.862	-.037	-.171	-.049	-.035
HX of CAD	-1.159	-.021	-.008	-.027	-.019
Hx of CABG	9.973	.084	.156	.108	.076
EMS transport Time*	.714	.454	.550	.522	.428
Prehospital STEMI Activation*	-13.607	-.256	-.342	-.333	-.247
Cardiologist arrival time*	.305	.217	.292	.290	.212
Lifesaving Measures*	12.580	.172	.198	.231	.166
Model 6:					
Age	.314	.160	.316	.208	.147
Gender	-2.218	-.044	-.171	-.060	-.041
HX of CAD	-1.381	-.025	-.008	-.032	-.022
Hx of CABG	10.351	.087	.156	.114	.079
EMS transport Time*	.726	.461	.550	.534	.435
Prehospital STEMI Activation*	-12.878	-.242	-.342	-.319	-.232
Cardiologist arrival time*	.258	.183	.292	.244	.173
Lifesaving Measures*	13.317	.182	.198	.247	.175
Cath Lab team arrival time	.232	.125	.222	.169	.118
Model 7:					
Age	.291	.148	.316	.196	.135
Gender	-1.621	-.032	-.171	-.044	-.030
HX of CAD	-1.405	-.025	-.008	-.033	-.023

Model	B	Beta	Zero-Order	Partial	Part
Hx of CABG	9.439	.079	.156	.106	.072
EMS transport Time*	.713	.453	.550	.532	.426
Prehospital STEMI Activation*	-9.717	-.183	-.342	-.229	-.159
Cardiologist arrival time	.230	.163	.292	.219	.152
Lifesaving Measures*	14.370	.196	.198	.267	.188
Cath Lab team arrival time	.273	.147	.222	.198	.137
Door to 1st MD time	.969	.141	.321	.180	.124

* Denotes a p-value < .005

The purpose of this analysis was to provide evidence relevant the fourth research question: Which process factor(s) has a statistically significant impact on the first medical contact to balloon time in patients presenting with a STEMI, at the level of each individual facility, while controlling for the factors of age, gender and history of coronary artery disease, and history of coronary artery bypass grafts? This question is answered by the 7th and final statistical model. This model accounts for over 54% of the variance in First medical contact to balloon times at this facility and is the best and most practical model of the predictors that have significant impact on FMC times. This model is very similar the overall FMC model with a few notable exceptions. The predictors Regular versus off hours and critical diagnostic exams did not have sufficient impact to be included in the final model. The predictors cath lab team arrival time and Door to first MD time, while only accounting for an additional 3% of the variance, were nevertheless included in the final model.

Facility B D2B analysis (RQ3). Patients (N = 113) were between the ages of 34 and 89 years old with a mean age of 60.89 (SD ± 11.37). The frequencies and percentages of the sample descriptive statistics are found in Table 21. A significant percentage of the sample patients were male (78.8%). A majority of the sample had no previous documented history of coronary artery disease (78.8%) and none of the sample patient had undergone coronary artery bypass surgery (100).

Table 21. Descriptive Statistics of Cases in the RQ3 Analysis at Facility B.

Variable	Mean	SD	Frequency	Percentage
Age:	60.89	11.37		
Gender:				
Male			89	78.8%
Female			24	21.2%
History of coronary artery disease:			89	78.8%
No			24	21.2%
Yes				
History of CABG:				
No			113	100%
Yes			0	0%

The dichotomous process factor variables are reported as the frequency and percentage and are found in Table 22. The variables day of the week and time of day were combined and recoded as the variable regular hours or off hours. Over half of the patients presented during off hours (55.8%). Most patients presented to the hospital via EMS (86.7%) and underwent a prehospital ECG (85.8%). This allowed for prehospital STEMI activation over half of the time (69%). A very minimal number of patients required lifesaving measures (10.6%) or critical diagnostic exams (4.4%) prior to PTCA. Just under one percent of patients had anatomical variances that delayed treatment of their condition. Finally, an overwhelming majority of patients had femoral artery access (99.1%) for their procedures.

Table 22. Description of Nominal Process Factors from RQ3 Analysis at Facility B.

Variable	Frequency	Percentage
Regular vs. off hours		
Regular	50	44.2%
Off	63	55.8%
Mode of arrival		
EMS	98	86.7%
Civilian	15	13.3%
Prehospital ECG		
Yes	97	85.8%
No	16	14.2%
Prehospital STEMI		
activation	78	69%
Yes	35	31%
No		
Lifesaving measures		
Yes	12	10.6%
No	101	89.4%
Critical diagnostic exams		
Yes	5	4.4%
No	108	95.6%
Anatomical variances		
Yes	1	0.9%
No	112	99.1%
Route of arterial access		
Femoral	112	99.1%
Radial	1	0.1%

The continuous variables are reported as the mean and standard deviation. The mean Door to triage time was 2.76 minutes (SD± 3.95). The mean Door to ECG time was 5.20 minutes (SD± 4.81). The mean Door to first physician contact time was 5.68 minutes (SD± 6.25). The mean Cardiologist arrival time was 26.45 minutes (SD± 15.01).

The mean Cath lab team arrival time was 17.13 minutes (SD± 14.27). The dependent variable of this analysis was Door to balloon time (D2B). D2B is reported as a mean and standard deviation. The mean Door to balloon time was 61.56 minutes (SD± 15.88).

A multiple linear regression analysis was conducted using the stratified sample (N = 113) and Door to balloon time as the dependent variable. The following predictors were used: Mode of arrival, Regular or off hours, Pre-hospital ECG, Pre-hospital STEMI activation, Door to triage, door to ECG, Door to 1st MD, Cardiologist arrival, cath lab response, Lifesaving measures, Critical diagnostic exams, and anatomical variances. The covariates of age, gender, history of CAD, and history of CABG were controlled. A stepwise insertion method was used for the predictors.

The standardized residuals were plotted in a scatterplot and assessed for normality and homoscedasticity. The standardized residuals were plotted on a histogram and assessed for skewness. The histogram was found to be normally distributed with a skewness statistic of 0.024 and SE of .227. The histogram is found in Figure 13. Mahalanobis distances were calculated and assessed. A total of 2 cases were found to be significant outliers. After further review it was determined that these cases should be excluded in order to improve the normality and homoscedasticity of the sample. This resulted in the revised sample size of 113. The scatterplot is seen in Figure 14.

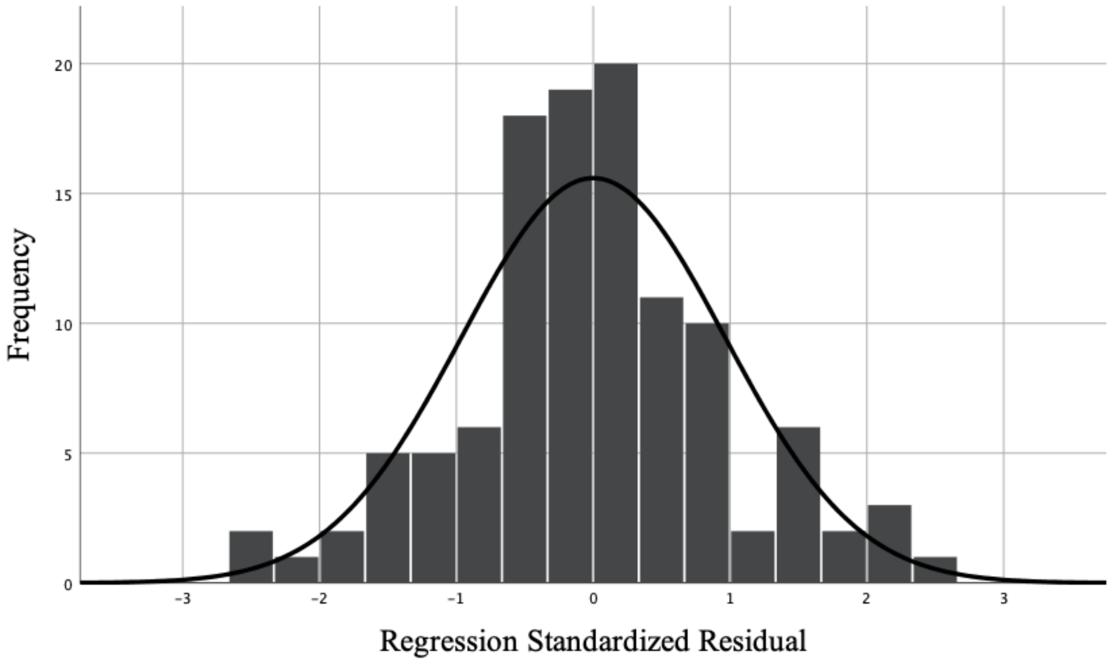

Figure 13. Standardized Residual Histogram of the RQ3 Analysis at Facility B.

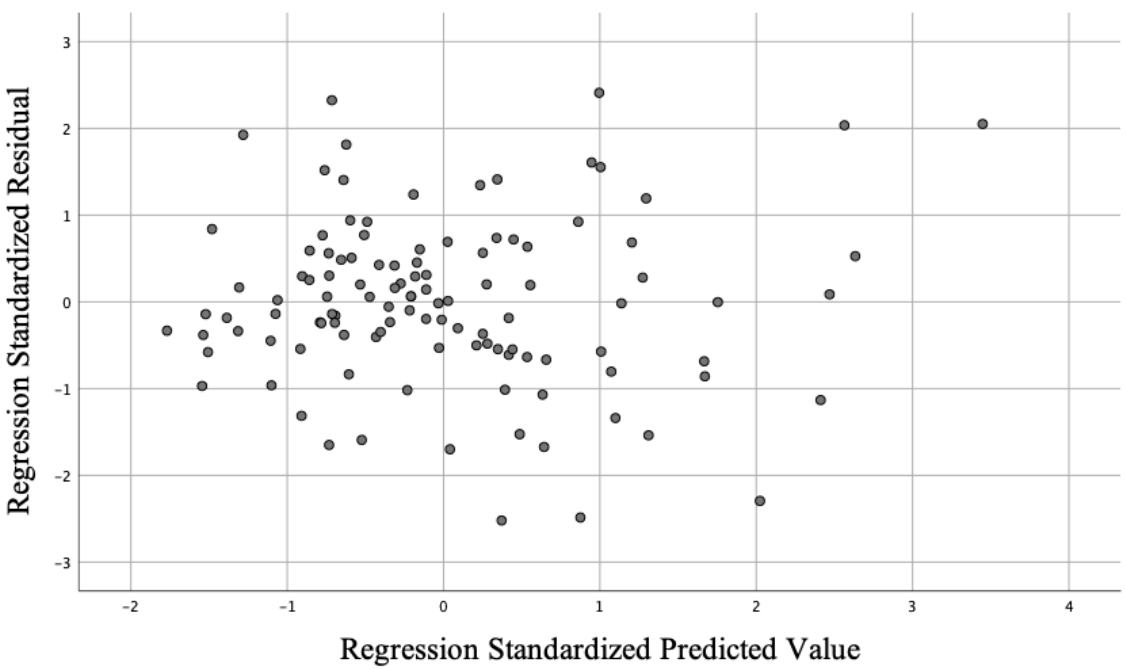

Figure 14. Standardized Residual Scatterplot of the RQ3 Analysis at Facility B.

This analysis yielded six separate models of the predictors; the complete model summary is found in Table 23. Model 1 was restricted to the covariates in order to control for them in subsequent models and resulted in and R^2 of .008. Model 2 inserted the predictor Door to ECG time and resulted in an increase of the R^2 of .156. Model 3 included both Door to ECG time and Regular vs off hours and resulted in an R^2 change of .181. Model 4 added the predictor Lifesaving measures and resulted in an R^2 change of .081. Model 5 added the predictor Cath lab team arrival time and resulted in an increase of the R^2 of 0.030. Finally, Model 6 added the predictor Prehospital STEMI activation and resulting in an R^2 change of .032. This regression model was significant with F (8, 104) = 12.44 with a p-value < 0.001. The predictors Door to triage time, Door to first MD time, Cardiologist arrival time, Mode of arrival, Prehospital ECG, Critical diagnostic exams, Anatomical Variances and Route of access did not meet the stepwise insertion criteria and, therefore, were excluded from the models.

Table 23. Summary of RQ3 Regression Models at Facility B.

Model	Variable added	R^2	Change in the R^2	F statistic	p-value
Model 1	Covariates	.008	.008	.307	.820
Model 2	Door to ECG time	.165	.156	5.33	.001
Model 3	Regular vs. off hours	.346	.181	11.32	<.001
Model 4	Lifesaving measures	.427	.081	13.17	<.001
Model 5	Cath lab team arrival time	.457	.030	12.62	<.001
Model 6	Prehospital STEMI activation	.489	.032	12.44	<.001

The regression coefficients for all six models were assessed and are found in Table 24. The introduction of the predictor Door to ECG time in the second model increased the beta, part and partial coefficients of all the covariates. Subsequently, the introduction of the predictor Regular versus off hours in model three significantly increased the coefficients for Door to ECG. The introduction of Lifesaving measures in the fourth model decreased some of the coefficients and increased others. The introduction of Cath lab team arrival time in the fifth model again increased nearly all of the coefficients of the previous predictors. Finally, the introduction of Prehospital STEMI activation in the final model caused both increases and decreased among the coefficients.

Table 24. Coefficient Values of the RQ3 Regression Models at Facility B.

Models	B	Beta	Zero-order	Partial	Part
Model 1:					
Age	-.010	-.007	.010	-.007	-.007
Gender	-1.859	-.048	-.032	-.046	-.046
HX of CAD	3.377	.087	.079	.086	.086
Model 2:					
Age	.045	.032	.010	.034	.031
Gender	-1.299	-.034	-.032	-.035	-.032
HX of CAD	3.981	.103	.079	.110	.101
Door to ECG time*	1.313	.398	.390	.397	.395
Model 3:					
Age	.083	.059	.010	.071	.057
Gender	-1.860	-.048	-.032	-.057	-.046
HX of CAD	2.976	.077	.079	.093	.075
Door to ECG time*	1.604	.486	.390	.505	.473
Regular vs off hours*	-13.893	-.437	-.339	-.466	-.426
Model 4:					
Age	.047	.034	.010	.043	.032
Gender	-2.518	-.065	-.032	-.082	-.063
HX of CAD	3.683	.095	.079	.122	.093

Models	B	Beta	Zero-order	Partial	Part
Door to ECG time*	1.549	.469	.390	.516	.456
Regular vs off hours*	-12.512	-.393	-.339	-.448	-.379
Lifesaving Measures*	14.844	.289	.348	.352	.285
Model 5:					
Age	.011	.008	.010	.010	.007
Gender	-3.080	-.080	-.032	-.103	-.076
HX of CAD	3.942	.102	.079	.134	.099
Door to ECG time*	1.565	.474	.390	.530	.461
Regular vs off hours*	-8.805	-.277	-.339	-.290	-.224
Lifesaving Measures*	15.661	.305	.348	.376	.299
Cath Lab team arrival time	.233	.210	.292	.228	.173
Model 6:					
Age	.026	.018	.010	.024	.018
Gender	-3.266	-.085	-.032	-.112	-.081
HX of CAD	4.325	.112	.079	.151	.109
Door to ECG time*	1.289	.391	.390	.435	.346
Regular vs off hours	-7.792	-.245	-.339	-.264	-.196
Lifesaving Measures*	15.138	.295	.348	.375	.289
Cath Lab team arrival time	.259	.233	.292	.258	.191
Prehospital STEMI Activation	-6.845	-.200	-.355	-.243	-.179

* Denotes a p-value < .005

The purpose of this analysis was to provide evidence relevant the third research question: Which process factor(s) has a statistically significant impact on the door to balloon time in patients presenting with a STEMI, at the level of each individual facility, while controlling for the factors of age, gender and history of coronary artery disease, and history of coronary artery bypass grafts? This question is answered by the 6th and final statistical model of this analysis. This model accounts for almost 49% of the variance in Door to balloon times at this facility. Taken as a set, these predictors make up the best and most practical model of the process factors that have significant impact on Door to balloon times at this facility. This model closely mirrors the overall D2B model with the exception of the predictor Cath lab team arrival time. While not present in the overall model, this predictor does account for and additional 3% of the explained variance of Door to balloon times.

Facility B FMC analysis (RQ4). In order to analyze First medical contact to balloon time, the Facility B sample was further stratified by Mode of arrival, and only the patients presenting via EMS were used in this analysis. Patients (N = 97) were between the ages of 34 and 89 years old with a mean age of 61.14 (SD ± 11.13). The frequencies and percentages of the sample descriptive statistics are found in Table 25. A significant percentage of the stratified sample patients were male (78.4%). A majority of the sample had no previous documented history of coronary artery disease (79.4%). None of the sample patients had previously undergone coronary artery bypass surgery.

Table 25. Descriptive Statistics of Cases in the RQ4 Analysis at Facility B.

Variable	Mean	SD	Frequency	Percentage
Age:	61.14	11.13		
Gender:			76	78.4%
Male			21	21.6%
Female				
History of coronary artery disease:				
No			77	79.4%
Yes			20	20.6%
History of CABG:				
No			97	100%
Yes			0	0%

The dichotomous process factor variables are reported as the frequency and percentage and are found in Table 26. The variables day of the week and time of day were combined and recoded as the variable regular hours or off hours. Over half of the patients presented during off hours (55.7%). Almost all patients underwent a prehospital ECG (99%). This allowed for prehospital STEMI activation just almost 80% of the time (79.4%). A very minimal number of patients required lifesaving measures (11.3%) or critical diagnostic exams (5.2%) prior to PTCA. Anatomical variances that delayed treatment were found in a minimal number of patients (1%). Finally, an overwhelming majority of patients had femoral artery access (99%) for their procedures.

Table 26. Description of Nominal Process Factors from RQ4 Analysis at Facility B.

Variable	Frequency	Percentage
Regular vs. off hours		
Regular	43	44.3%
Off	54	55.7%
Prehospital ECG		
Yes	96	99%
No	1	1%
Prehospital STEMI		
activation	77	79.4%
Yes	20	20.6%
No		
Lifesaving measures		
Yes	11	11.3%
No	86	88.7%
Critical diagnostic exams		
Yes	5	5.2%
No	92	94.8%
Anatomical variances		
Yes	1	1%
No	96	99%
Route of arterial access		
Femoral	96	99%
Radial	1	1%

The continuous variables are reported as the mean and standard deviation. The mean Door to triage time was 2.34 minutes (SD± 2.45). The mean Door to ECG time was 4.53 minutes (SD± 3.84). The mean Door to first physician contact time was 5.05 minutes (SD± 5.94). The mean Cardiologist arrival time was 26.56 minutes (SD± 15.27). The mean Cath lab team arrival time was 18.05 minutes (SD± 14.14). The mean EMS transport time was 26.01 minutes (SD± 9.89). The dependent variable of this analysis was First medical contact to balloon time (FMC). FMC time is reported as a mean and standard deviation. The mean First medical contact to balloon time was 86.40 minutes (SD± 18.99).

A multiple linear regression analysis was conducted using the stratified sample (N = 97). First medical contact to balloon time was used as the dependent variable as well as the following predictors; Regular or off hours, EMS transport time, Pre-hospital ECG, Pre-hospital STEMI activation, Door to triage, door to ECG, Door to 1st MD, Cardiologist arrival, cath lab response, Lifesaving measures, Critical diagnostic exams, and anatomical variances. The covariates of age, gender, history of CAD, and history of CABG were controlled. A stepwise insertion method was used for the predictors. Due to the relatively small sample size it was necessary to run the analysis with an expected effect size of .30, alpha of .005, and a power of .80.

The standardized residuals were plotted in a scatterplot and assessed for normality and homoscedasticity. The standardized residuals were plotted on a histogram and assessed for skewness. The histogram was minimally negatively skewed with a skewness statistic of -0.110 and SE of .245. The histogram is found in Figure 15. Mahalanobis distances were calculated and assessed. A total of 3 cases were found to be significant outliers. After further review it was determined that these cases should be excluded in order to improve the normality and homoscedasticity of the sample. This resulted in the revised sample size of 97. The scatterplot is seen in Figure 16.

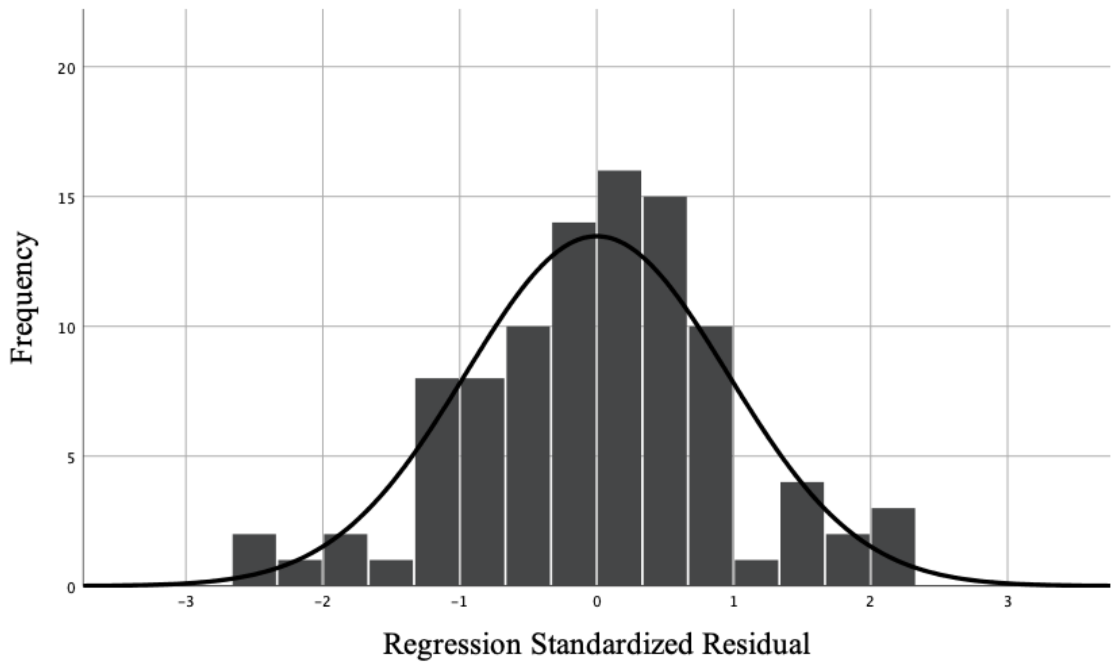

Figure 15. Standardized Residual Histogram of the RQ4 Analysis at Facility B.

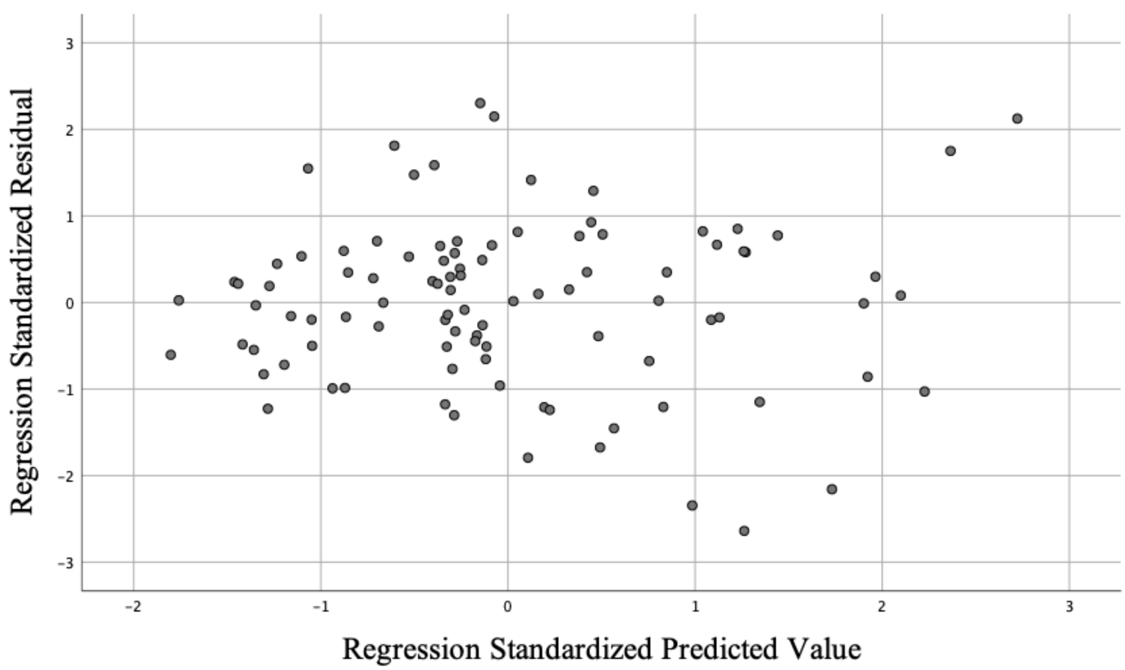

Figure 16. Standardized Residual Scatterplot of the RQ4 Analysis at Facility B.

This analysis yielded six separate models of the predictors; the complete model summary is found in Table 27. Model 1 was restricted to the covariates in order to control for them in subsequent models and resulted in and R^2 of .028. Model 2 inserted the predictor EMS transport time and resulted in an R^2 change of .237. Model 3 added the predictor Lifesaving measures and resulted in an R^2 change of .116. Model 4 added the predictor Prehospital STEMI activation and resulted in an increase of the R^2 of .083. Model 5 added the predictor Cath lab team arrival time and resulted in an R^2 change of .052. Model 6 added the predictor Door to ECG time and resulted in an R^2 change of .033. This regression model was significant with $F(8, 88) = 13.37$ with a p-value $< .001$. The predictors Door to triage time, Door to first MD time, Cardiologist arrival time, Prehospital ECG, Critical diagnostic exams, Anatomical variances and Route of access did not meet the stepwise insertion criteria and, therefore, were excluded from the models.

Table 27. Summary of RQ4 Regression Models at Facility B.

Model	Variable added	R^2	Change in the R^2	F statistic	p-value
Model 1	Covariates	.028	.028	.892	.449
Model 2	EMS transport time	.264	.237	8.27	<.001
Model 3	Lifesaving measures	.381	.116	11.18	<.001
Model 4	Prehospital STEMI activation	.464	.083	12.97	<.001
Model 5	Cath lab team arrival time	.516	.052	13.54	<.001
Model 6	Door to ECG time	.549	.033	13.37	<.001

The regression coefficients for all six models were assessed and can be found in Table 28. The introduction of the predictor EMS transport time in the second model decreased the beta, part and partial coefficients of all the covariates. Subsequently, the introduction of Lifesaving measures in model three decreased both the beta and part coefficients for EMS transport time while increasing the partial. The introduction of Prehospital STEMI activation in the fourth model again decreased the coefficients of both previous predictors. The introduction of Cath lab team arrival time in the fifth model saw an increase in the coefficients of all the previous predictors. Finally, the introduction of Door to ECG time in the sixth model increased the previous predictors coefficients.

Table 28. Coefficient Values of the RQ4 Regression Models at Facility B.

Models	B	Beta	Zero-order	Partial	Part
Model 1:					
Age	.112	.065	.093	.065	.064
Gender	-5.219	-.114	-.099	-.111	-.110
HX of CAD	5.176	.111	.096	.108	.107
Model 2:					
Age	.062	.036	.093	.041	.036
Gender	-3.383	-.074	-.099	-.083	-.071
HX of CAD	2.898	.062	.096	.069	.060
EMS transport Time*	.943	.491	.505	.493	.486
Model 3:					
Age	.039	.023	.093	.029	.023
Gender	-4.142	-.090	-.099	-.110	-.087
HX of CAD	3.580	.077	.096	.093	.074
EMS transport Time*	.897	.467	.505	.506	.462
Lifesaving Measures*	20.388	.342	.369	.397	.341
Model 4:					
Age	.114	.067	.093	.088	.065
Gender	-4.442	-.097	-.099	-.126	-.093
HX of CAD	4.502	.096	.096	.125	.092

Models	B	Beta	Zero-order	Partial	Part
EMS transport Time*	.817	.426	.505	.494	.416
Lifesaving Measures*	18.032	.303	.369	.378	.299
Prehospital STEMI Activation*	-13.896	-.298	-.376	-.366	-.288
Model 5:					
Age	.050	.029	.093	.040	.028
Gender	-5.452	-.119	-.099	-.162	-.114
HX of CAD	4.521	.097	.096	.132	.093
EMS transport Time*	.856	.446	.505	.530	.435
Lifesaving Measures*	18.980	.319	.369	.411	.314
Prehospital STEMI Activation*	-13.187	-.282	-.376	-.365	-.273
Cath Lab team arrival time*	.313	.233	.184	.311	.228
Model 6:					
Age	.043	.025	.093	.036	.024
Gender	-5.440	-.119	-.099	-.167	-.114
HX of CAD	5.235	.112	.096	.158	.107
EMS transport Time*	.864	.450	.505	.547	.438
Lifesaving Measures*	17.925	.301	.369	.402	.295
Prehospital STEMI Activation*	-10.363	-.222	-.376	-.291	-.204
Cath Lab team arrival time*	.324	.241	.184	.331	.236
Door to ECG time	.960	.194	.298	.261	.182

* Denotes a p-value < .005

The purpose of this analysis was to provide evidence relevant the fourth research question: Which process factor(s) has a statistically significant impact on the first medical contact to balloon time in patients presenting with a STEMI, at the level of each individual facility, while controlling for the factors of age, gender and history of coronary artery disease, and history of coronary artery bypass grafts? This question is answered by the 6th and final statistical model of this analysis. This model accounts for almost 55% of the variance in first medical contact to balloon times at this facility. The predictors in this model are also found in the overall FMC model with one exception, the predictor Cath lab team arrival time. While not present in the overall model this predictor was found to be significant in this facility's analysis and also accounts for over 5% of the explained variance in FMC times.

Facility C D2B analysis (RQ3). Patients (N = 153) were between the ages of 35 and 89 years old with a mean age of 65 (SD ± 12). The frequencies and percentages of the sample descriptive statistics are found in Table 29. A significant percentage of the sample patients were male (73.2%). A majority of the sample had no previous documented history of coronary artery disease (77.8%) and a majority had not undergone coronary artery bypass surgery (96.7%).

Table 29. Descriptive Statistics of Cases in the RQ3 Analysis Facility C.

Variable	Mean	SD	Frequency	Percentage
Age:	65	12		
Gender:				
Male			112	73.2%
Female			41	26.8%
History of coronary artery disease:			119	77.8%
No			34	22.2%
Yes				
History of CABG:				
No			148	96.7%
Yes			5	3.3%

The dichotomous process factor variables are reported as the frequency and percentage and are found in Table 30. The variables day of the week and time of day were combined and recoded as the variable regular hours or off hours. Over half of the patients presented during off hours (51.6%). Most patients presented to the hospital via EMS (64.1%) and underwent a prehospital ECG (64.1%). This allowed for prehospital STEMI activation less than half of the time (47.7%). A very minimal number of patients required lifesaving measures (9.2%) or critical diagnostic exams (6.5%) prior to PTCA. A small number of patients had anatomical variances that delayed treatment of their condition (2.6%). Finally, an overwhelming majority of patients had femoral artery access (94.8%) for their procedures.

Table 30. Description of Nominal Process Factors from RQ3 Analysis at Facility C.

Variable	Frequency	Percentage
Regular vs. off hours		
Regular	74	48.4%
Off	79	51.6%
Mode of arrival		
EMS	98	64.1%
Civilian	55	35.9%
Prehospital ECG		
Yes	98	64.1%
No	55	35.9%
Prehospital STEMI		
activation	73	47.7%
Yes	80	52.3%
No		
Lifesaving measures		
Yes	14	9.2%
No	139	90.8%
Critical diagnostic exams		
Yes	10	6.5%
No	143	93.5%
Anatomical variances		
Yes	4	2.6%
No	149	97.4%

Route of arterial access		
Femoral	145	94.8%
Radial	8	5.2%

The continuous variables are reported as the mean and standard deviation. The mean Door to triage time was 6.79 minutes (SD± 6.35). The mean Door to ECG time was 6.83 minutes (SD± 9.60). The mean Door to first physician contact time was 7.13 minutes (SD± 7.98). The mean Cardiologist arrival time was 42.16 minutes (SD± 15.39). The mean Cath lab team arrival time was 36.29 minutes (SD± 15.74). The dependent variable of this analysis was Door to balloon time (D2B). D2B is reported as a mean and standard deviation. The mean Door to balloon time was 67.55 minutes (SD± 22.03).

A multiple linear regression analysis was conducted using the stratified sample (N = 153) and Door to balloon time as the dependent variable. The following predictors were used: Mode of arrival, Regular or off hours, Pre-hospital ECG, Pre-hospital STEMI activation, Door to triage, door to ECG, Door to 1st MD, Cardiologist arrival, cath lab response, Lifesaving measures, Critical diagnostic exams, and anatomical variances. The covariates of age, gender, history of CAD, and history of CABG were controlled. A stepwise insertion method was used for the predictors.

The standardized residuals were plotted in a scatterplot and assessed for normality and homoscedasticity. The standardized residuals were plotted on a histogram and assessed for skewness. The histogram was mildly positively skewed with a skewness statistic of 0.282 and SE of .196. The histogram is found in Figure 17. Mahalanobis distances were calculated and assessed. A total of 2 cases were found to be significant outliers. After further review it was determined that these cases should be excluded in order to improve the normality and homoscedasticity of the sample. This resulted in the revised sample size of 153. The scatterplot is seen in Figure 18.

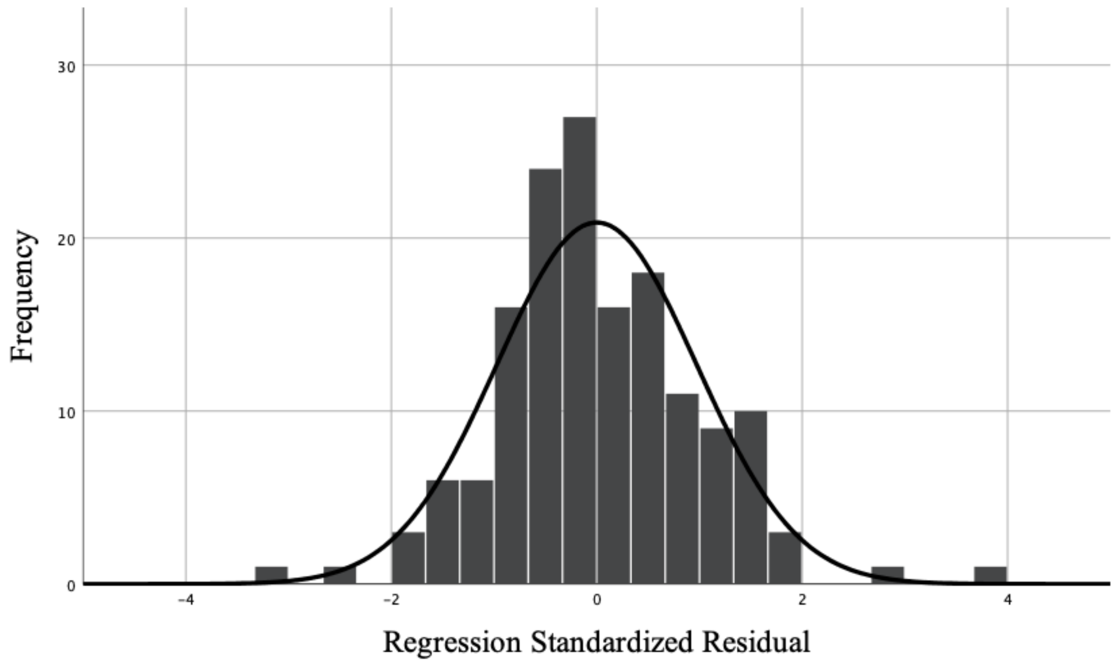

Figure 17. Standardized Residual Histogram of the RQ3 Analysis at Facility C.

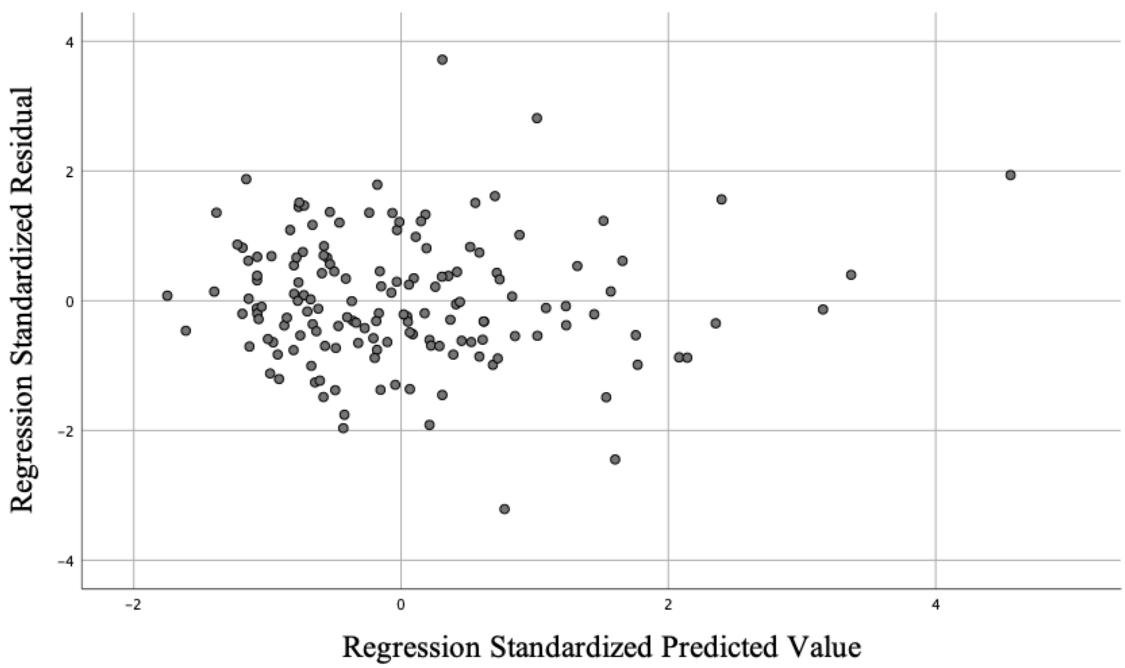

Figure 18. Standardized Residual Scatterplot of the RQ3 Analysis at Facility C.

This analysis yielded five separate models of the predictors; the complete model summary is found in Table 31. Model 1 was restricted to the covariates in order to control for them in subsequent models and resulted in and R^2 of .060. Model 2 inserted the predictor Door to ECG time and resulted in an R^2 change of .227. Model 3 included both Door to ECG time and Lifesaving measures and resulted in an increase of the R^2 of .134. Model 4 added the predictor Prehospital STEMI activation and resulting in an R^2 change of .098. Finally, model 5 added the predictor Cardiologist arrival time and resulted in an R^2 change of .113. This regression model was significant with $F(8, 144) = 30.90$ with a p-value < .001.The predictors Door to triage time, Cath lab team arrival time, Prehospital ECG, Critical diagnostic exams, Anatomical variances, Regular versus off hours and Route of access did not meet the stepwise insertion criteria and, therefore, were excluded from the models.

Table 31. Summary of RQ3 Regression Models at Facility C.

Model	Variable added	R^2	Change in the R^2	F statistic	p-value
Model 1	Covariates	.060	.060	2.37	.055
Model 2	Door to ECG time	.287	.227	11.84	<.001
Model 3	Lifesaving measures	.421	.134	17.68	<.001
Model 4	Prehospital STEMI activation	.519	.098	22.36	<.001
Model 5	Cardiologist arrival time	.632	.113	30.91	<.001

The regression coefficients for all five models were assessed and are found in Table 32. The introduction of the predictor Door to ECG time in the second model increased the beta while decreasing the part and partial coefficients the covariates. Subsequently, the introduction of Lifesaving measures in model three decreased both the beta and part and partial coefficients for Door to ECG time. The introduction of Prehospital STEMI activation in the fourth model again decreased the coefficients of both previous predictors. Finally, the introduction of Cardiologist arrival time in the final model decreased most all of the coefficients of the previous predictors.

Table 32. Coefficient Values of the RQ3 Regression Models at Facility C.

Models	B	Beta	Zero-order	Partial	Part
Model 1:					
Age	.117	.064	.121	.063	.061
Gender	-10.407	-.210	-.224	-.201	-.199
HX of CAD	-.099	-.002	-.012	-.002	-.002
Hx of CABG	9.221	.075	.072	.072	.070
Model 2:					
Age	-.005	-.003	.121	-.003	-.003
Gender	-7.087	-.143	-.224	-.157	-.134
HX of CAD	1.147	.022	-.012	.024	.020
Hx of CABG	10.897	.088	.072	.097	.083
Door to ECG time*	1.123	.489	.509	.491	.476
Model 3:					
Age	.098	.054	.121	.066	.051
Gender	-5.953	-.120	-.224	-.147	-.113
HX of CAD	2.803	.053	-.012	.064	.049
Hx of CABG	11.470	.093	.072	.114	.087
Door to ECG time*	1.004	.437	.509	.485	.422
Lifesaving Measures*	28.576	.375	.423	.433	.366
Model 4:					
Age	.168	.092	.121	.123	.086
Gender	-4.676	-.094	-.224	-.126	-.088
HX of CAD	3.861	.073	-.012	.096	.067
Hx of CABG	5.474	.044	.072	.059	.041
Door to ECG time*	.816	.355	.509	.432	.332

Models	B	Beta	Zero-order	Partial	Part
Lifesaving Measures*	26.748	.351	.423	.442	.341
Prehospital STEMI Activation*	-14.559	-.331	-.468	-.412	-.314
Model 5:					
Age	.173	.094	.121	.144	.088
Gender	-3.306	-.067	-.224	-.102	-.062
HX of CAD	4.408	.083	-.012	.125	.076
Hx of CABG	3.262	.026	.072	.040	.024
Door to ECG time*	.753	.328	.509	.450	.306
Lifesaving Measures*	22.539	.296	.423	.424	.284
Prehospital STEMI Activation*	-15.926	-.362	-.468	-.491	-.342
Cardiologist arrival time*	.492	.344	.415	.484	.336

* Denotes p-value < .005

The purpose of this analysis was to provide evidence relevant the third research question: Which process factor(s) has a statistically significant impact on the door to balloon time in patients presenting with a STEMI, at the level of each individual facility, while controlling for the factors of age, gender and history of coronary artery disease, and history of coronary artery bypass grafts? This question is answered by the 5th and final statistical model of this analysis. This model accounts for over 63% of the variance in Door to balloon times at this facility and is clearly the strongest model of the predictors that have significant impact on Door to balloon times. This model closely mirrors that of the overall D2B model with all four predictors being present in the overall model as well as other facilities' D2B models.

Facility C FMC analysis (RQ4). In order to analyze First medical contact to balloon time, the Facility C sample was further stratified by Mode of arrival, and only the patients presenting via EMS were used in this analysis (N = 95). Patients were between the ages of 37 and 89 years old with a mean age of 65.68 (SD ± 11.52). The frequencies and percentages of the sample descriptive statistics are found in Table 33. A significant percentage of the stratified sample patients were male (73.7%). A majority of the sample had no previous documented history of coronary artery disease (73.7%). None of the sample patients had undergone previous coronary artery bypass surgery (100%).

Table 33. Descriptive Statistics of Cases in the RQ4 Analysis at Facility C.

Variable	Mean	SD	Frequency	Percentage
Age:	65.68	11.52		
Gender:			70	73.7%
Male			25	26.3%
Female				
History of coronary artery disease:				
No			70	73.7%
Yes			25	26.3%
History of				
CABG:			95	100%
No			0	0%
Yes				

The dichotomous process factor variables are reported as the frequency and percentage and are found in Table 34. The variables day of the week and time of day were combined and recoded as the variable regular hours or off hours. Over half of the patients presented during off hours (50.5%). All patients underwent a prehospital ECG

(100%). This allowed for prehospital STEMI activation just over 75% of the time (75.8%). A very minimal number of patients required lifesaving measures (12.6%) or critical diagnostic exams (8.4%) prior to PTCA. Anatomical variances that delayed treatment were found in a minimal number of patients (3.2%). Finally, an overwhelming majority of patients had femoral artery access (92.6%) for their procedures.

Table 34. Description of Nominal Process Factors from RQ4 Analysis at Facility C.

Variable	Frequency	Percentage
Regular vs. off hours		
Regular	47	50.5%
Off	48	49.5%
Prehospital ECG		
Yes	85	100%
No	0	0%
Prehospital STEMI activation	72	75.8%
Yes	23	24.2%
No		
Lifesaving measures		
Yes	12	12.6%
No	83	87.4%
Critical diagnostic exams		
Yes	8	8.4%
No	87	91.6%
Anatomical variances		
Yes	3	3.2%
No	92	96.8%
Route of arterial access		
Femoral	88	92.6%
Radial	7	7.4%

The continuous variables are reported as the mean and standard deviation. The mean Door to triage time was 6.06 minutes (SD± 5.82). The mean Door to ECG time was 6.07 minutes (SD± 6.86). The mean Door to first physician contact time was 4.63 minutes (SD± 6.80). The mean Cardiologist arrival time was 43.82 minutes (SD± 16.80).

The mean Cath lab team arrival time was 38.17 minutes (SD± 16.22). The mean EMS transport time was 27.71 minutes (SD± 15.45). The dependent variable of this analysis was First medical contact to balloon time (FMC). FMC time is reported as a mean and standard deviation. The mean FMC to balloon time was 92.57 minutes (SD± 26.98).

A multiple linear regression analysis was conducted using the stratified sample. First medical contact to balloon time was used as the dependent variable as well as the following predictors; Regular or off hours, EMS transport time, Pre-hospital ECG, Pre-hospital STEMI activation, Door to triage, door to ECG, Door to 1st MD, Cardiologist arrival, cath lab response, Lifesaving measures, Critical diagnostic exams, and anatomical variances. The covariates of age, gender, history of CAD, and history of CABG were controlled. A stepwise insertion method was used for the predictors.

The standardized residuals were plotted in a scatterplot and assessed for normality and homoscedasticity. The standardized residuals were plotted on a histogram and assessed for skewness. The histogram was mildly positively skewed with a skewness statistic of 0.281 and SE of .247. The histogram is found in Figure 19. Mahalanobis distances were calculated and assessed. A total of 3 cases were found to be significant outliers. After further review it was determined that these cases should be excluded in order to improve the normality and homoscedasticity of the sample. This resulted in the revised sample size of 95. The scatterplot is seen in Figure 20.

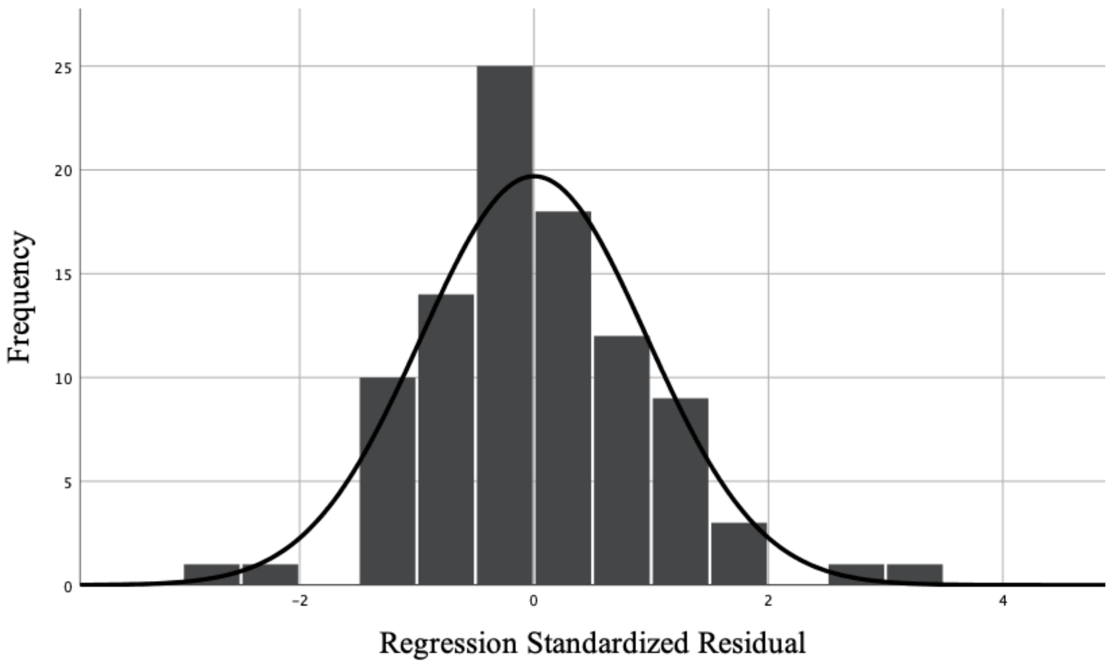

Figure 19. Standardized Residual Histogram of the RQ4 Analysis at Facility C.

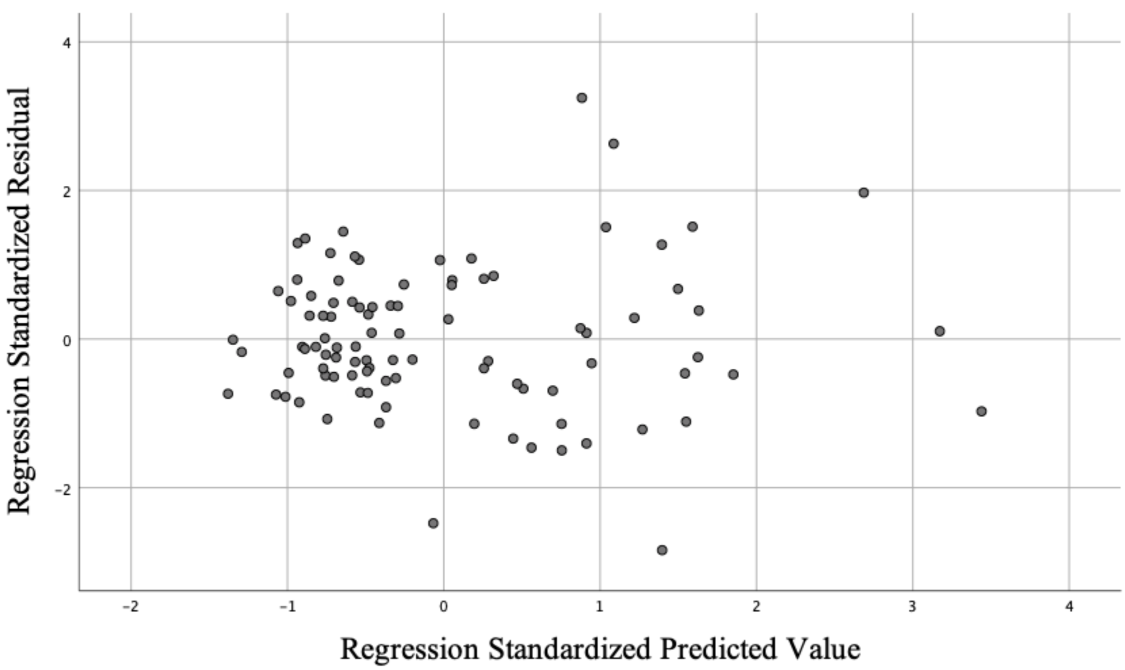

Figure 20. Standardized Residual Scatterplot of the RQ4 Analysis at Facility C.

This analysis yielded five separate models of the predictors; the complete model summary is found in Table 35. Model 1 was restricted to the covariates in order to control for them in subsequent models and resulted in and R^2 of .041. Model 2 inserted the predictor Cardiologist arrival time and resulted in an R^2 change of .285. Model 3 added the predictor Prehospital STEMI activation and resulted in an R^2 change of .172. Model 4 added the predictor EMS transport time and resulted in an R^2 change of .176. Finally, model 5 added the predictor Lifesaving measures and resulted in an R^2 change of .073. This regression model was significant with $F(7, 87) = 36.58$ with a p-value $< .001$.The predictors Door to first MD time, Cath lab team arrival time, Critical diagnostic exams, Anatomical variances, regular versus off hours and Route of access did not meet the stepwise insertion criteria and, therefore, were excluded from the models.

Table 35. Summary of RQ4 Regression Models at Facility C.

Model	Variable added	R^2	Change in the R^2	F statistic	p-value
Model 1	Covariates	.041	.041	1.31	.277
Model 2	Cardiologist arrival time	.326	.285	10.87	<.001
Model 3	Prehospital STEMI activation	.497	.172	17.62	<.001
Model 4	EMS transport time	.673	.176	30.22	<.001
Model 5	Lifesaving measures	.746	.073	36.58	<.001

The regression coefficients for all five models were assessed and are found in Table 36. The introduction of the predictor Cardiologist arrival time in the second model increased the beta, part and partial coefficients of the covariates. Subsequently, the introduction of Prehospital STEMI activation in model three had a mixed effect on the coefficients. The introduction of EMS transport time in the fourth model decreased the coefficients of both previous predictors. Finally, the introduction of Lifesaving measures in the final model increased the betas of the predictors while decreasing the part and partial coefficients of all the previous predictors.

Table 36. Coefficient Values of the RQ4 Models at Facility C.

Models	B	Beta	Zero-order	Partial	Part
Model 1:					
Age	.336	.144	.161	.144	.142
Gender	-7.467	-.123	-.145	-.121	-.119
HX of CAD	-.676	-.011	-.036	-.011	-.011
Model 2:					
Age	.372	.159	.161	.188	.157
Gender	-1.694	-.028	-.145	-.032	-.027
HX of CAD	1.124	.018	-.036	.022	.018
Cardiologist arrival time*	.873	.543	.546	.545	.533
Model 3:					
Age	.367	.157	.161	.214	.155
Gender	2.881	.047	-.145	.063	.045
HX of CAD	-2.807	-.046	-.036	-.063	-.045
Cardiologist arrival time*	.808	.503	.546	.570	.491
Prehospital STEMI Activation*	-26.718	-.427	-.475	-.505	-.414
Model 4:					
Age	.173	.074	.161	.125	.072
Gender	-1.245	-.020	-.145	-.033	-.019
HX of CAD	.229	.004	-.036	.006	.004
Cardiologist arrival time*	.552	.343	.546	.482	.315
Prehospital STEMI Activation*	-30.063	-.480	-.475	-.629	-.463
EMS transport time*	.804	.461	.527	.591	.419
Model 5:					
Age	.294	.126	.161	.232	.120
Gender	-2.153	-.035	-.145	-.065	-.033

Models	B	Beta	Zero-order	Partial	Part
HX of CAD	4.061	.067	-.036	.123	.063
Cardiologist arrival time*	.482	.300	.546	.476	.272
Prehospital STEMI Activation*	-22.546	-.360	-.475	-.535	-.319
EMS transport time*	.839	.481	.527	.655	.437
Lifesaving Measures*	24.926	.309	.437	.473	.270

* Denotes a p-value < .005

The purpose of this analysis was to provide evidence relevant the fourth research question: Which process factor(s) has a statistically significant impact on the first medical contact to balloon time in patients presenting with a STEMI, at the level of each individual facility, while controlling for the factors of age, gender and history of coronary artery disease, and history of coronary artery bypass grafts? This question is clearly answered by the 5th and final statistical model of this analysis. This model accounts for almost 75% of the variance in first medical contact to balloon times at this facility. The predictors of this model are all present in other facilities' FMC models as well as the overall model.

Facility D D2B analysis (RQ3). Patients (N = 130) were between the ages of 28 and 86 years old with a mean age of 62.48 (SD ± 11.98). The frequencies and percentages of the sample descriptive statistics are found in Table 37. A significant percentage of the sample patients were male (69.2%). A majority of the sample had no previous documented history of coronary artery disease (83.8%) and a majority had not undergone coronary artery bypass surgery (97.7%).

Table 37. Descriptive Statistics of Cases in the RQ3 Analysis Facility D.

Variable	Mean	SD	Frequency	Percentage

Age:	62.48	11.98		
Gender:				
Male			90	69.2%
Female			40	30.8%
History of coronary artery disease:			130	83.8%
No			21	16.2%
Yes				
History of CABG:				
No			127	97.7%
Yes			3	2.3%

The dichotomous process factor variables are reported as frequencies and percentages and are found in Table 38. The variables day of the week and time of day were combined and recoded as the variable regular hours or off hours. Over half of the patients presented during off hours (53.1%). Over half of the patient presented via EMS (55.4%) Most patients underwent a prehospital ECG (53.8%). The use of prehospital ECG allowed for prehospital STEMI activation in just over 40% of the time (41.5%). A very small percentage of patients required lifesaving measures (10%) or critical diagnostic exams (2.3%) prior to PTCA. Anatomical variances that delayed treatment were not found in this sample of patients (0%). Finally, all of the patients in this sample had femoral artery access (100%) for their procedures.

Table 38. Description of Nominal Process Factors from RQ3 Analysis at Facility D.

Variable	Frequency	Percentage
Regular vs. off hours		
Regular	61	46.9%
Off	69	53.1%
Prehospital ECG		

Yes	60	46.2%
No	70	53.8%
Prehospital STEMI activation	76	58.5%
Yes	54	41.5%
No		
Lifesaving measures		
Yes	13	10%
No	117	90%
Critical diagnostic exams		
Yes	3	2.3%
No	130	97.7%
Anatomical variances		
Yes	0	0%
No	130	100%
Route of arterial access		
Femoral	130	100%
Radial	0	0%

The continuous variables are reported as the mean and standard deviation. The mean Door to triage time was 5.65 minutes (SD± 7.44). The mean Door to ECG time was 5.24 minutes (SD± 6.52). The mean Door to first physician contact time was 8.34 minutes (SD± 8.50). The mean Cardiologist arrival time was 39.40 minutes (SD± 9.99). The mean Cath lab team arrival time was 23.62 minutes (SD± 10.26). The dependent variable of this analysis was Door to balloon time (D2B). D2B time is reported as a mean and standard deviation. The mean Door to balloon time was 66.75 minutes (SD± 17.30).

A multiple linear regression analysis was conducted using the stratified sample (N = 130) and Door to balloon time as the dependent variable. The following predictors were used: Mode of arrival, Regular or off hours, Pre-hospital ECG, Pre-hospital STEMI activation, Door to triage, door to ECG, Door to 1st MD, Cardiologist arrival, cath lab response, Lifesaving measures, Critical diagnostic exams, and anatomical variances. The covariates of age, gender, history of CAD, and history of CABG were controlled. A stepwise insertion method was used for the predictors.

The standardized residuals were plotted in a scatterplot and assessed for normality and homoscedasticity. The standardized residuals were plotted on a histogram and assessed for skewness. The histogram was positively skewed with a skewness statistic of 1.46 and SE of .212. The histogram is found in Figure 21. Mahalanobis distances were calculated and assessed. A total of 5 cases were found to be significant outliers. After further review it was determined that these cases should be excluded in order to improve the normality and homoscedasticity of the sample. This resulted in the revised sample size of 130. The scatterplot is illustrated in Figure 22.

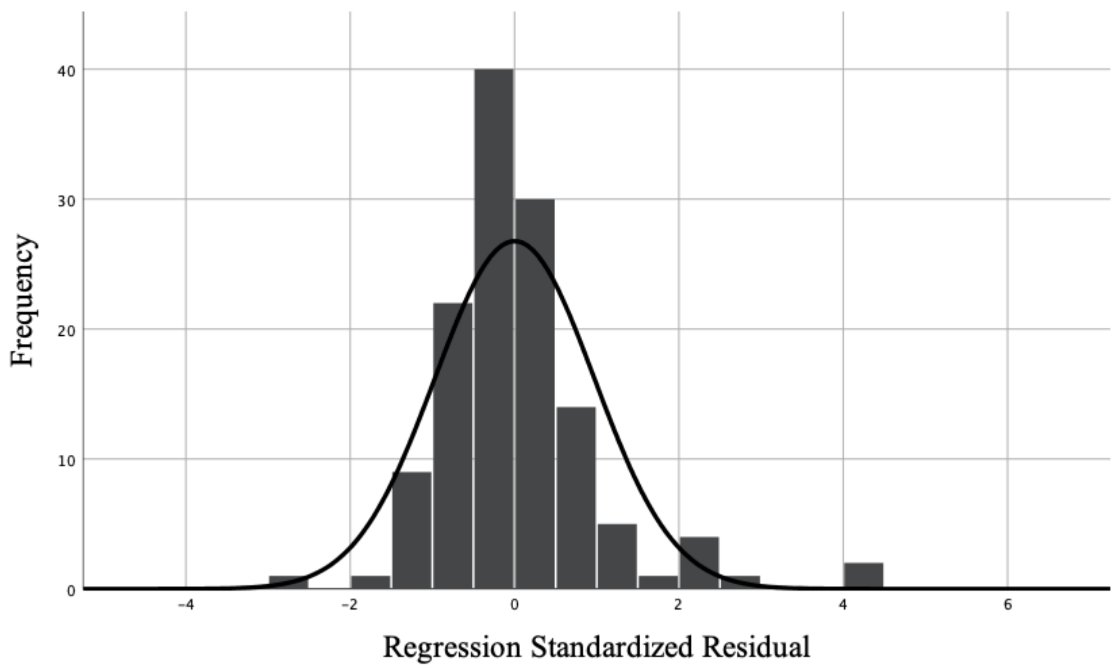

Figure 21. Standardized Residual Histogram of the RQ3 Analysis at Facility D.

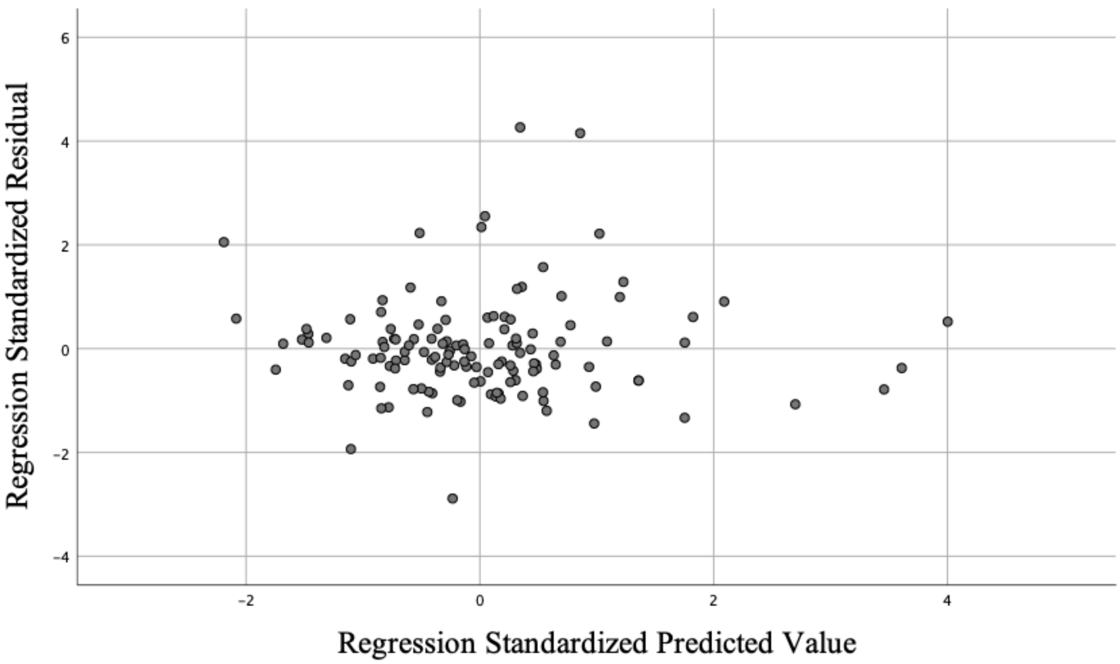

Figure 22. Standardized Residual Scatterplot of the RQ3 Analysis at Facility D.

This analysis yielded five separate models of the predictors; the complete model summary is found in Table 39. Model 1 was restricted to the covariates in order to control for them in subsequent models and resulted in and R^2 of .005. Model 2 inserted the predictor Door to ECG time and resulted in an R^2 change of .283. Model 3 included both Door to ECG time and Cardiologist arrival time and resulted in an R^2 change of .172. Model 4 added the predictor Prehospital STEMI activation and resulted in an R^2 change of .041. Finally, model 5 added the predictor Cath lab team arrival time and resulted in an R^2 change of .016. This regression model was significant with F (8, 121) = 16.18 with a p-value < .001. The predictors Door to triage time, Door to first MD time, Mode of arrival, Prehospital ECG, lifesaving measures, critical diagnostic exams, Regular versus off hours and Route of access did not meet the stepwise insertion criteria and, therefore, were excluded from the models.

Table 39. Summary of RQ3 Regression Models at Facility D.

Model	Variable added	R^2	Change in the R^2	F statistic	p-value
Model 1	Covariates	.005	.005	.150	.963
Model 2	Door to ECG time	.288	.283	10.01	<.001
Model 3	Cardiologist arrival time	.460	.172	17.44	<.001
Model 4	Prehospital STEMI activation	.501	.041	17.47	<.001
Model 5	Cath lab team arrival time	.517	.016	16.18	<.001

The regression coefficients for all five models were assessed and are found in Table 40. The introduction of the predictor Door to ECG time in the second model increase beta, part and partial coefficients of nearly all the covariates with the exception of Age. Subsequently, the introduction of Cardiologist arrival time in model three decreased both the beta and part coefficients for Door to ECG time while increase the partial. The introduction of Prehospital STEMI activation in the fourth model decreased the coefficients of both previous predictors while increasing and decreasing those of the covariates. Finally, the introduction of Cath lab team arrival time in the final model decreased the coefficients of all the previous predictors.

Table 40. Coefficient Values of the RQ3 Regression Models at Facility D.

Models	B	Beta	Zero-order	Partial	Part
Model 1:					
Age	.000	.000	-.018	.000	.000
Gender	1.150	.031	.032	.031	.031
HX of CAD	-1.900	-.041	-.053	-.037	-.037
Hx of CABG	-3.890	-.034	-.048	-.032	-.032

Models	B	Beta	Zero-order	Partial	Part
Model 2:					
Age	-.078	-.054	-.018	-.061	-.052
Gender	1.167	.031	.032	.037	.031
HX of CAD	2.604	.056	-.053	.059	.050
Hx of CABG	-1.674	-.015	-.048	-.016	-.014
Door to ECG time*	1.439	.542	.531	.533	.532
Model 3:					
Age	-.041	-.028	-.018	-.037	-.027
Gender	1.126	.030	.032	.041	.030
HX of CAD	5.317	.114	-.053	.137	.101
Hx of CABG	-.915	-.008	-.048	-.010	-.007
Door to ECG time*	1.351	.509	.531	.561	.498
Cardiologist arrival time*	.733	.423	.458	.492	.415
Model 4:					
Age	-.006	-.004	-.018	-.005	-.004
Gender	.810	.022	.032	.030	.022
HX of CAD	5.103	.109	-.053	.136	.097
Hx of CABG	3.038	.026	-.048	.035	.024
Door to ECG time*	1.155	.435	.531	.493	.401
Cardiologist arrival time*	.781	.451	.458	.527	.438
Prehospital STEMI Activation*	-7.704	-.220	-.315	-.275	-.202
Model 5:					
Age	.010	.007	-.018	.010	.007
Gender	1.543	.041	.032	.058	.041
HX of CAD	4.949	.106	-.053	.134	.094
Hx of CABG	2.869	.025	-.048	.033	.023
Door to ECG time*	1.089	.410	.531	.472	.372
Cardiologist arrival time*	.709	.409	.458	.478	.379
Prehospital STEMI Activation*	-8.370	-.239	-.315	-.299	-.217

Models	B	Beta	Zero-order	Partial	Part
Cath Lab team arrival time	.235	.140	.302	.181	.128

* Denotes a p-value < .005

The purpose of this analysis was to provide evidence relevant to the third research question: Which process factor(s) has a statistically significant impact on the door to balloon time in patients presenting with a STEMI, at the level of each individual facility, while controlling for the factors of age, gender and history of coronary artery disease, and history of coronary artery bypass grafts? This question is answered by the 5th and final statistical model. This model accounts for over 51% of the variance in Door to balloon times at this facility. This model also closely mirrors the overall D2B model, in that three of the four predictors are also present in the overall model. The one exception was the predictor cath lab team arrival time, which only accounted for 1.6% of the explained variance.

Facility D FMC analysis (RQ4). In order to analyze First medical contact to balloon time, the Facility D sample was further stratified by Mode of arrival, and only the patients presenting via EMS were used in this analysis (N = 75). Patients were between the ages of 28 and 86 years old with a mean age of 64.70 (SD ± 12.21). The frequencies and percentages of the sample descriptive statistics are found in Table 41. A significant percentage of the stratified sample patients were male (60.8%). A majority of the sample had no previous documented history of coronary artery disease (78.4%) nor had undergone previous coronary artery bypass surgery (95.9%).

Table 41. Descriptive Statistics of EMS Patients from the RQ4 Analysis at Facility D.

Variable	Mean	SD	Frequency	Percentage
Age:	64.70	12.21		

Gender:		
Male	45	60.8%
Female	29	39.2%
History of coronary artery disease:		
No	58	78.4%
Yes	16	21.6%
History of CABG:		
No	71	95.9%
Yes	3	4.1%

The dichotomous process factor variables are reported as the frequency and percentage and are found in Table 42. The variables day of the week and time of day were combined and recoded as the variable regular hours or off hours. Over half of the patients presented during off hours (55.4%). Almost all patients underwent a prehospital ECG (97.3%). This allowed for prehospital STEMI activation just over 75% of the time (75.7%). A very minimal number of patients required lifesaving measures (16.2%) or critical diagnostic exams (4.1%) prior to PTCA. Anatomical variances that delayed treatment were found in a minimal number of patients (2.7%). Finally, an overwhelming majority of patients had femoral artery access (98.6%) for their procedures.

Table 42. Description of Nominal Process Factors from RQ3 Analysis at Facility D.

Variable	Frequency	Percentage
Regular vs. off hours		
Regular	33	44.6%
Off	41	55.4%
Prehospital ECG		
Yes	72	97.3%
No	2	2.7%

Prehospital STEMI activation	56	75.7%
Yes	18	24.3%
No		
Lifesaving measures		
Yes	12	16.2%
No	62	83.8%
Critical diagnostic exams		
Yes	3	4.1%
No	71	95.9%
Anatomical variances		
Yes	2	2.7%
No	72	97.3%
Route of arterial access		
Femoral	73	98.6%
Radial	1	1.4%

The continuous variables are reported as the mean and standard deviation. The mean Door to triage time was 6.28 minutes (SD± 9.04). The mean Door to ECG time was 4.22 minutes (SD± 5.32). The mean Door to first physician contact time was 6.31 minutes (SD± 7.04). The mean Cardiologist arrival time was 40.55 minutes (SD± 9.77). The mean Cath lab team arrival time was 23.91 minutes (SD± 10.51). The mean EMS transport time was 26.96 minutes (SD± 10.27). The dependent variable of this analysis was First medical contact to balloon time (FMC). FMC time is reported as a mean and standard deviation. The mean First medical contact to balloon time was 90.77 minutes (SD± 21.14).

A multiple linear regression analysis was conducted using the stratified sample. First medical contact to balloon time was used as the dependent variable as well as the following predictors; Regular or off hours, EMS transport time, Pre-hospital ECG, Pre-hospital STEMI activation, Door to triage, door to ECG, Door to 1st MD, Cardiologist arrival, cath lab response, Lifesaving measures, Critical diagnostic exams, and anatomical variances. The covariates of age, gender, history of CAD, and history of CABG were controlled. A stepwise insertion method was used for the predictors.

The standardized residuals were plotted in a scatterplot and assessed for normality and homoscedasticity. The standardized residuals were plotted on a histogram and assessed for skewness. The histogram was positively skewed with a skewness statistic of 0.794 and SE of .279. The histogram is found in Figure 23. Mahalanobis distances were calculated and assessed. Only one case was found to be a significant outlier. After further review it was determined that this case should be excluded in order to improve the normality and homoscedasticity of the sample. This resulted in the revised sample size of 74. The scatterplot is illustrated in Figure 24.

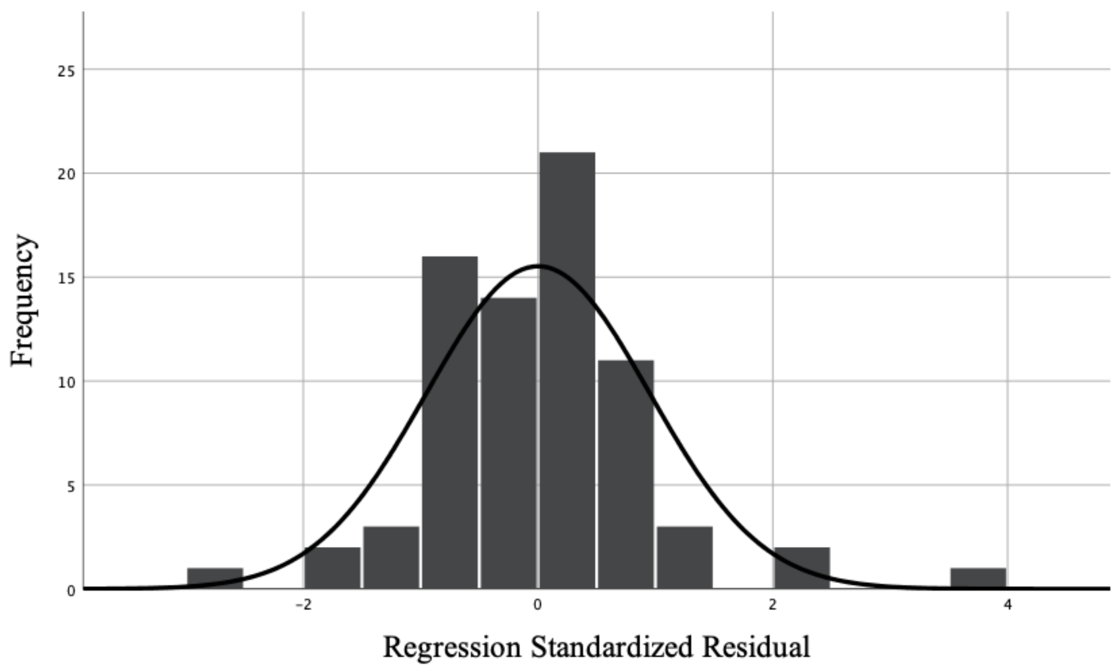

Figure 23. Standardized Residual Histogram of the RQ4 Analysis at Facility D.

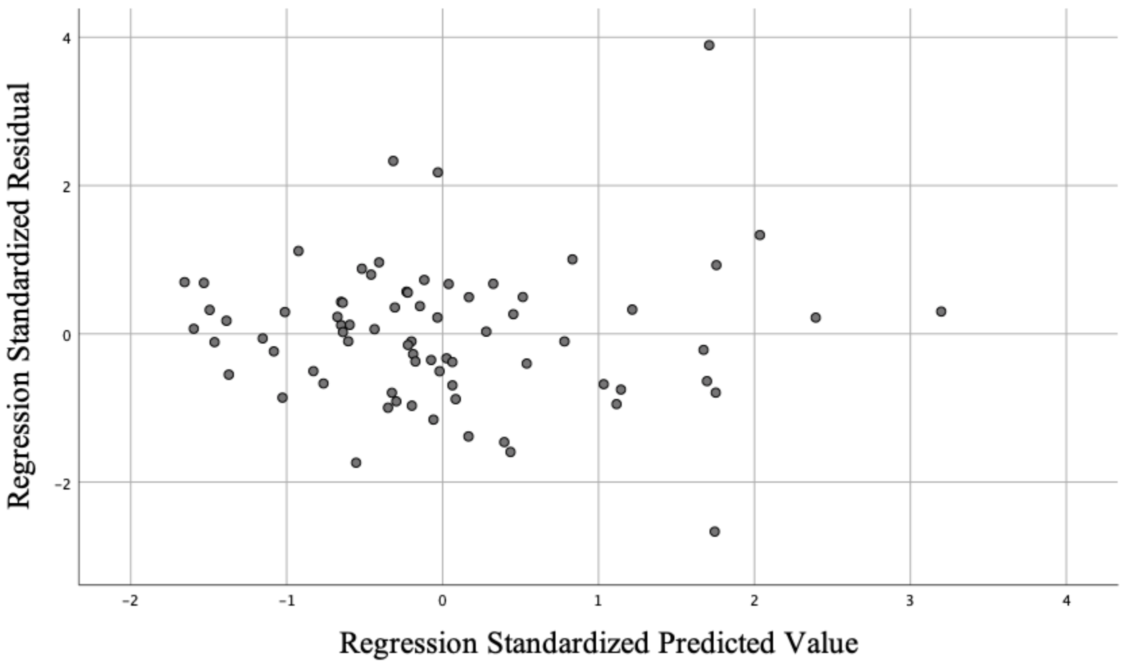

Figure 24. Standardized Residual Scatterplot of the RQ4 Analysis at Facility D.

This analysis yielded four separate models of the predictors; the complete model summary is found in Table 43. Model 1 was restricted to the covariates in order to control for them in subsequent models and resulted in and R^2 of .014. Model 2 inserted the predictor EMS transport time and resulted in an R^2 change of .274. Model 3 added the predictor Cardiologist arrival time and resulted in an R^2 change of .273. Finally, model 4 added the predictor Door to ECG time and resulted in an R^2 change of .110. This regression model was significant with $F(7, 66) = 19.26$ with a p-value $< .001$. The predictors Door to triage time, Door to first MD time, Cath lab team arrival time, Prehospital ECG, Prehospital STEMI activation, Lifesaving measures, Critical diagnostic exams, Anatomical variances, regular versus off hours and Route of access did not meet the stepwise insertion criteria and therefore were excluded from the models.

Table 43. Summary of RQ4 Regression Models at Facility D.

Model	Variable added	R^2	Change in the R^2	F statistic	p-value
Model 1	Covariates	.014	.014	0.253	.907
Model 2	EMS transport time	.288	.274	5.51	<.001
Model 3	Cardiologist arrival time	.561	.273	14.27	<.001
Model 4	Door to ECG time	.671	.110	19.26	<.001

The regression coefficients for all four models were assessed and are found in Table 44. The introduction of the predictor EMS transport time in the second model significantly impacted beta, part and partial coefficients of the covariates. Subsequently, the introduction of Cardiologist arrival time in model three increased the coefficients for both EMS transport time and the covariates. Finally, the introduction of Door to ECG time in the final model decreased the coefficients of the previous predictors while increasing those of the covariates.

Table 44. Coefficient Values of the Regression Models at Facility D.

Models	B	Beta	Zero-order	Partial	Part
Model 1:					
Age	.059	.034	.043	.033	.033
Gender	-2.194	-.051	-.052	-.051	-.051
HX of CAD	4.691	.092	.064	.083	.083
Hx of CABG	-9.503	-.089	-.050	-.082	-.082
Model 2:					
Age	.131	.076	.043	.087	.073
Gender	2.787	.065	-.052	.075	.063
HX of CAD	1.156	.023	.064	.024	.020
Hx of CABG	-4.473	-.042	-.050	-.046	-.038
EMS transport Time*	1.114	.541	.527	.527	.523

Models	B	Beta	Zero-order	Partial	Part
Model 3:					
Age	.148	.086	.043	.124	.083
Gender	4.290	.100	-.052	.145	.097
HX of CAD	4.077	.080	.064	.107	.071
Hx of CABG	.414	.004	-.050	.005	.004
EMS transport Time*	1.135	.551	.527	.627	.533
Cardiologist arrival time*	1.149	.531	.503	.619	.522
Model 4:					
Age	.050	.029	.043	.048	.028
Gender	5.655	.131	-.052	.217	.127
HX of CAD	6.384	.125	.064	.190	.111
Hx of CABG	1.767	.017	-.050	.026	.015
EMS transport Time*	1.071	.520	.527	.658	.501
Cardiologist arrival time*	.990	.457	.503	.609	.440
Door to ECG time*	1.397	.352	.471	.501	.332

* Denotes a p-value < .005

The purpose of this analysis was to provide evidence relevant to the fourth research question: Which process factor(s) has a statistically significant impact on the first medical contact to balloon time in patients presenting with a STEMI, at the level of each individual facility, while controlling for the factors of age, gender and history of coronary artery disease, and history of coronary artery bypass grafts? This question is clearly answered by the 4th and final statistical model. This model accounts for over 67% of the variance in first medical contact to balloon times at this facility and is the best and most practical model of the predictors that have significant impact on FMC times. While this model contained only three predictors, all of them were also present in the overall FMC model.

Model Comparisons

A significant number of predictors were common to nearly all the models. The predictor Prehospital STEMI activation was present in the overall D2B model as well as all of the individual facility models. The predictors Cardiologist arrival time and Door to ECG time were also present in the overall D2B model as well as three of the four facility models. Finally, the predictors Lifesaving measures and regular versus off hours were found in the overall D2B model as well as half of the facility models.

As expected, the predictor EMS transport time was found in the overall FMC model as well as all of the individual facility FMC models. The predictors Prehospital STEMI activation, Cardiologist arrival time, and Lifesaving measures were also present in the overall FMC model as well as three of the four facility models. The predictor Door to ECG time was present in the overall model as well as half of the facility models. This clearly shows that the predictors Prehospital STEMI activation, Cardiologist arrival time, Lifesaving measures, and Door to ECG time are significant process factors that impact both Door to Balloon time and First medical contact to balloon time regardless of the facility.

Summary

The results of this analysis have provided statistically significant models that answer all four of the research questions that guided this study. RQ1 was answered by the Door to balloon model containing the following predictors: Prehospital STEMI activation, Cardiologist arrival time, Lifesaving measures, Door to ECG time, Regular versus off hours, and Critical diagnostic exams. Together these predictors account for almost 43% of the variance of Door to Balloon times. RQ2 was answered by the First Medical contact to balloon model containing the following predictors: EMS transport time, Prehospital STEMI activation, Cardiologist arrival time, Lifesaving measures, Door to ECG time, Regular versus off hours, and Critical diagnostic exams. Together these predictors account for over 69% of the variance of First medical contact tot balloon times.

RQ 3 was answered by the four separate Door to balloon time models at the individual facility level. Facility A's model included; Prehospital STEMI activation, Cardiologist arrival time, Door to ECG time, Regular versus off hours, Critical diagnostic exams, and Anatomical variances. Together these predictors account for almost 44% of the variance of Door to Balloon times at this facility. Facility B's model included; Prehospital STEMI activation, Door to ECG time, Regular versus off hours, Lifesaving measures, and Cath lab team arrival time. Together these predictors account for almost 49% of the variance of Door to Balloon times at this facility. Facility C 's model; includes; Door to ECG time, Lifesaving measures, Prehospital STEMI activation, and Cardiologist arrival time. Together these predictors account for over 63% of the variance of Door to Balloon times at this facility. Facility D 's model includes; Door to ECG time, Cardiologist arrival time, Prehospital STEMI activation, Cath lab team arrival time. Together these predictors account for almost 52% of the variance of Door to Balloon times at this facility.

RQ 4 was answered by the four separate First Medical contact to balloon time models at the individual facility level. Facility A's model included; EMS transport time, Prehospital STEMI activation, Cardiologist arrival time, Lifesaving measures, Cath lab team arrival time, and Door to first MD time. Together these predictors account for over 54% of the variance of First medical contact to Balloon times at this facility. Facility B's model included; EMS transport time, Prehospital STEMI activation, Door to ECG time, Lifesaving measures, and Cath lab team arrival time. Together these predictors account for almost 55% of the variance of First medical contact to Balloon times at this facility. Facility C 's model; includes; EMS transport time, Lifesaving measures, Prehospital STEMI activation, and Cardiologist arrival time. Together these predictors account for over 74% of the variance of First medical contact to Balloon times at this facility. Facility D 's model includes; EMS transport time, Door to ECG time, and Cardiologist arrival time. Together these predictors account for over 67% of the variance of First medical contact to Balloon times at this facility.

This chapter reported the results of the analyses of Door to balloon time and First medical contact to balloon time as well as the sub analyses at the individual facility level. The results reported include the statistically significant models and the amount of variance of the reperfusion times explained by each model. The results also included the unstandardized and standardized regression coefficients for the predictors of each model. The following chapter, chapter 5, will discuss the results in detail as well as discuss the impact of these results and implications for STEMI programs at the individual facility level. It will also address the limitations of the research study and make suggestions for future research on this topic.

CHAPTER 5: DISCUSSION

Chapter one established the emergent nature of a STEMI and the importance of the STEMI treatment process. Chapter one also defined the aims and research questions that guided this study. The second chapter reviewed significant literature with regards to the process factors involved with the identification and treatment of a STEMI as well as detailing the theoretical framework used in this study. Chapter three defined the research design and methodology as well as describing the study setting, sampling method and variables used in the study. Finally, the procedures used to extract the data and subsequent statistical analyses are also addressed. Chapter four provided a brief overview of the data preparation procedures as well as reporting of the descriptive statistics of the complete sample and the individual facility samples. The statistical analyses used were described, and the results and subsequent statistical models reported.

The impact of process factors on the reperfusion times in patients presenting with a STEMI was examined. This chapter includes a discussion of the results and conclusions of the study. This chapter also discusses the limitations of the research study, the implications of the results for STEMI programs, as well as recommendations for future research regarding STEMI process factors.

Outcomes

Predictors of D2B time (RQ1). The initial analysis of the revised complete sample (N = 618) using Door to balloon time, resulted in a total of ten regression models.

Table 45 shows these models and the variance explained by each. Model one was restricted to the covariates age, gender, history of CAD, and history of CABG in order to control for them in subsequent models. Together the covariates accounted for 1.7% of the variance of the Door to balloon times. Models two through eight added the following predictors, respectively: Prehospital STEMI activation, Cardiologist arrival time, Lifesaving measures, Door to ECG time, Regular versus off hours, Critical diagnostic exams, and Door to first MD time. Together these predictors and the covariates account for almost 55% of the variance of Door to balloon time. A majority of the variance can be attributed to the predictor Prehospital STEMI activation, which accounts for almost 17% of the variance alone. Subsequently, the predictors Cardiologist arrival time, Lifesaving measures, Door to ECG time, and Regular versus off hours together account for and additional 22.9% of the variance explained in the final model. The remaining predictors, together, account for less than 2% of the variance. Therefore, it should be noted that model 6 is the best model from a practical standpoint.

Table 45. Variance accounted for by predictors of D2B time (RQ1).

Model	Variables added	Variance added	Total variance
Model 1	Covariates	1.7%	1.7%
Model 2	Prehospital STEMI activation	16.9%	18.7%
Model 3	Cardiologist arrival time	11.5%	30.2%
Model 4	Lifesaving measures	5.5%	35.7%
Model 5	Door to ECG time	4.3%	40.0%

Model 6	Regular vs. off hours	1.7%	41.7%
Model 7	Critical diagnostic exams	1.2%	42.9%
Model 8	Door to 1st MD time	0.7%	43.6%

Analysis of the unstandardized B coefficients of the predictors, as reported in Table 6, allows for a more practical understanding of the magnitude of the individual predictors impact Door to balloon times. The B coefficients of model 6, which were found to be significant with a p-value < .001, allow for predictions with regard to the impact of the significant process factors. This model predicts that the use of Prehospital STEMI activation can be associated with an over 12-minute reduction in Door to balloon times. While, a 5-minute decrease in Cardiologist arrival time likely results in a reduction of D2B time by only 1.75 minutes. The need for Lifesaving measures prior to PCI can increase D2B times by over 14 minutes. Furthermore, a 5-minute decrease in the Door to ECG time is associated with only a 4.1-minute decrease in Door to Balloon time. Finally, the model shows that STEMI patients presenting during regular hours may have Door to balloon times up to 5 minutes shorter than those presenting during off hours. This is due to the cath lab staff already being on site during regular hours and having a 30-minute response time during off hours.

Predictors of FMC to balloon time (RQ2). The analysis of First medical contact to balloon time necessitated a sample stratified by Mode of arrival (N = 422). This analysis resulted in a total of eight regression models. A complete breakdown of the models can be found in Table 46. The first model included only the covariates in order to control for them in subsequent models and accounted for 5.8% of the variance of First Medical contact to balloon time. The second through the eighth models added the following predictors, respectively: EMS transport time, Prehospital STEMI activation, Cardiologist arrival time, Lifesaving measures, Door to ECG time, Regular versus off hours, and Critical diagnostic exams. The combination of these predictors as well as the covariates accounts for almost 60% of the variance of First medical contact to balloon times. As expected, the predictors EMS transport time and Prehospital STEMI activation accounted for a significant amount of the explained variance. Together, these two predictors account for 36% of the explained variance. The predictors Cardiologist arrival time and Lifesaving measures contributed an additional 13% of the variance.

Table 46. Variance accounted for by predictors of FMC time (RQ2).

Model	Variables added	Variance added	Total variance
Model 1	Covariates	5.8%	5.8%
Model 2	EMS transport time	23.9%	29.7%
Model 3	Prehospital STEMI activation	12.1%	41.8%
Model 4	Cardiologist arrival time	8.0%	49.8%
Model 5	Lifesaving measures	5.1%	54.9%
Model 6	Door to ECG time	2.3%	57.2%
Model 7	Regular vs. off hours	1.2%	58.4%

Model 8	Critical diagnostic exams	1.1%	59.5%

Analysis of the B coefficients of model 8 from the FMC analysis were reported in Table 11. These analyses allow for a more practical picture of how each of the individual predictors impact FMC to balloon times. The B coefficients, which were found to be significant with a p-value < .001, indicate that a 5-minute decrease in EMS transport time can correspond with an almost 4.5-minute decrease in the First medical contact to balloon time. The use of Prehospital STEMI activation can be associated with an over 11-minute reduction in FMC to balloon time. The model also shows that a decrease of 5 minutes in Cardiologist arrival time can result in a reduction of FMC to balloon time by just over one minute. Conversely, the need for lifesaving measures prior to PCI can increase FMC to balloon time by over 10 minutes. The model also shows that a 5-minute decrease in the Door to ECG time can be associated with an over 4-minute decrease in FMC to Balloon time. Furthermore, patients presenting during off hours are likely to have FMC to balloon times over 5-minutes higher than those presenting during regular hours. Furthermore, the need for Critical diagnostic exams prior to PCI can increase FMC to balloon time by over 13 minutes.

As expected, the lists of significant predictors for both Door to balloon time and First medical contact to balloon time have much in common. Prehospital STEMI activation and Cardiologist arrival time are by far the most significant predictors present in both models. Lifesaving measures, Door to ECG time, Critical diagnostic exams, and Regular versus off hours were also common to both models. However, the final D2B model also contained the predictor Door to first MD time. However, this predictor accounted for less than 1% of the explained variance.

Predictors of D2B and FMC times at Individual Facilities (RQ3 and RQ4). In order to develop D2B statistical models for each of the participating facilities the complete sample (N = 647) was stratified by facility and separate multiple regression analyses were run in order to establish predictors for Door to balloon time at each facility. Similarly, to develop FMC statistical models for each of the participating facilities the complete sample (N = 647) was first stratified by facility and then the resulting samples were further stratified by mode of arrival and only those cases arriving via EMS were used. Multiple regression analyses were run to establish predictors for First medical contact to balloon time at each facility.

Facility A D2B (RQ3). The analysis of Door to balloon time utilized a stratified sample of 237 cases and resulted in a total of eight regression models. A complete list of the predictors and variances can be found in Table 47. The first model was restricted to the covariates in order to control for them in subsequent models. The covariates accounted for 5.2% of the variance of Door to balloon time.

Table 47. Variance accounted for by predictors of D2B at Facility A (RQ3)

Model	Variables added	Variance added	Total variance
Model 1	Covariates	5.2%	5.2%
Model 2	Prehospital STEMI activation	17.2%	22.4%
Model 3	Cardiologist arrival time	8.7%	31.1%

Model 4	Critical diagnostic exams	4.5%	35.6%
Model 5	Door to ECG time	4.9%	40.5%
Model 6	Anatomical variances	1.9%	42.4%
Model 7	Regular vs. off hours	1.6%	44.0%

Subsequently, models 2 through 7 added the following predictors, respectively: Prehospital STEMI activation, Cardiologist arrival time, Critical diagnostic exams, Door to ECG time, Anatomical variances, and Regular versus off hours. Taken as a set with the covariates these predictors account for 43.9% of the variance of Door to balloon time at this facility. Prehospital STEMI activation and Cardiologist arrival time were the predictors that together accounted for a majority of the variance at over 25%

Analysis of the B coefficients of model 7 from the Facility A D2B analysis were reported in Table 15. This analysis provides insights that are more directly applicable to the facility's STEMI program. The model coefficients, which were mostly found to be significant with a p-value < .001, show that the use of Prehospital STEMI activation can be associated with an over 14-minute reduction in Door to balloon times. However, a reduction of 5 minutes in cardiologist arrival time would only result in a 1.5-minute reduction in D2B time. The model also shows that the need for Critical diagnostic exams prior to PCI has the potential to increase Door to balloon time by over 25 minutes. If Door to ECG time is decreased by 5 minutes, Door to balloon time can decrease by over

4 minutes. The presence of anatomical variances can increase D2B times by over 13 minutes. Finally, the analysis found that patients presenting during off hours are likely to have D2B times over 5 minutes higher than those presenting during regular hours. These results nearly mirror those found in the overall predictors of D2B analysis. This provides clear evidence that these process factors do have a significant impact on Door to balloon times.

Facility A FMC (RQ4). The analysis of First medical contact to balloon time utilized a stratified sample of 157 cases collected from this facility. This analysis resulted in a total of seven regression models. A complete list of the predictors and their associated variances can be found in Table 48. The first model was restricted to the covariates for statistical control in subsequent models. Surprisingly, the covariates accounted for over 13% of the variance of First medical contact to balloon time. The remaining models added the following predictors, respectively: EMS transport time, Prehospital STEMI activation, Cardiologist arrival time, Lifesaving measures, Cath lab team arrival time, and Door to first MD time. Together with the covariates these predictors account for over 54% of the variance of First medical contact to balloon time at this facility.

Table 48. Variance accounted for by Predictors of FMC time at Facility A (RQ4).

Model	Variables added	Variance added	Total variance
Model 1	Covariates	13.3%	13.3%
Model 2	EMS transport time	23.1%	36.4%
Model 3	Prehospital STEMI activation	7.0%	43.4%

Model 4	Cardiologist arrival time	5.0%	48.4%
Model 5	Lifesaving measures	2.8%	51.2%
Model 6	Cath lab team arrival time	1.4%	52.6%
Model 7	Door to first MD time	1.5%	54.1%

Analysis of the B coefficients of the complete model, as reported in Table 20, provides information that can be more easily used in performance improvement measure. The model coefficients, which were for the most part statistically significant with p-values < .005, indicate that 5-minute decrease in the EMS transport time corresponds with a 3.5-minute reduction in FMC to balloon time. Subsequently, the use of Prehospital STEMI activation is associated with an over 9-minute reduction in FMC to balloon times. A 5-minute decrease in Cardiologist arrival time could result in a reduction of FMC to balloon time by just over one minute. The need for lifesaving measures is associated with an almost 14-minute increase in FMC to balloon times. A 5-minute decrease in Cath lab team arrival time can be associated with only about a 1-minute decrease in FMC to balloon time. Finally, A 5-minute decrease in Door to first MD time was associated with about them same decrease in FMC time. The coefficients of Cath lab arrival time and Door to first MD time were not statistically significant.

Facility B D2B (RQ3). This analysis of Door to balloon time utilized a stratified sample of 113 cases from this facility. This analysis resulted in a total of six regression models. A complete list of the predictors and their variances can be found in Table 49. The first model was restricted to covariates in order to control for them in subsequent models. The covariates only accounted for 0.8% of the variance of Door to balloon time. Subsequent models added the predictors Door to ECG time, Regular versus off hours, Lifesaving measures, Cath lab team arrival time, and Prehospital STEMI activation. The predictor Door to ECG time accounted for 15.6% of the explained variance. The predictor Regular versus off hours accounted for an additional 18.1% of the variance. The predictor Lifesaving measures accounted for 8.1% of the variance. The final two predictors accounted for an additional 6.2% of the variance.

Table 49. Variance accounted for by predictors of D2B at Facility B (RQ3).

Model	Variables added	Variance added	Total variance
Model 1	Covariates	0.8%	0.8%
Model 2	Door to ECG time	15.6%	16.5%
Model 3	Regular vs. off hours	18.1%	34.6%
Model 4	Lifesaving measures	8.1%	42.7%
Model 5	Cath lab team arrival time	3.0%	45.7%
Model 6	Prehospital STEMI activation	3.2%	48.9%

Analysis of the Beta coefficients of the final model from Table 24 provides more insight into how the individual predictors impact Door to balloon times. The model coefficients, which were mostly found to be significant with a p-value of .001, show that a 5-minute decrease in the Door to ECG time can be associated with an over 6-minute decrease in Door to Balloon time. Furthermore, the time of day and day of the week that the patient presents also have a significant impact on D2B time. Door to balloon time can be reduced by over 7 minutes when the patient presents during regular hours instead of off hours. This predictor was expected to be significant due to the 30-minute response of the cath lab team time during off hours. The analysis also indicated that the need for lifesaving measures prior to PCI can increase D2B time by over 15 minutes. While Prehospital STEMI activation can decrease D2B time by almost 7 minutes. Finally, a 5-minute decrease in the Cath lab team arrival time would have minimal impact, only resulting in a 1.6-minute reduction in D2B times.

Facility B FMC (RQ4). The analysis of First medical contact to balloon time utilized a stratified sample of 97 cases from this facility. The analysis resulted in a total of six regression models. A complete list of the models and variances can be found in Table 50. The first model was restricted to the covariates in order to control for them in subsequent models. The covariates accounted for only 2.8% of the variance of First medical contact to balloon time. The rest of the models added the predictors EMS transport time, Lifesaving measures, Prehospital STEMI activation, Cath lab team arrival time, and Door to ECG time. Together these predictors accounted for an additional 52% of the total variance explained.

Table 50. Variance accounted for by predictors of FMC at Facility B (RQ4).

Model	Variables added	Variance added	Total variance
Model 1	Covariates	2.8%	2.8%
Model 2	EMS transport time	23.7%	26.5%
Model 3	Lifesaving measures	11.6%	38.1%
Model 4	Prehospital STEMI activation	8.3%	46.4%
Model 5	Cath lab team arrival time	5.2%	51.6%
Model 6	Door to ECG time	3.3%	54.9%

Analysis of the B coefficients of the final model from Table 28 provides a more useful understanding of the direct impact of the individual predictors on FMC to balloon times. The model coefficients were found to be significant with a p-value < .001, indicate that 5-minute reduction in the EMS transport time can be associated with a 4.5-minute reduction in FMC to balloon time. The model also indicates that the need for lifesaving measures can increase FMC to balloon time by almost 18 minutes and Prehospital STEMI activation can decrease the FMC time by over 10 minutes. The cath lab team arrival time had minimal effect on the FMC time with a 5-minute decrease only resulting in 1.6-minute decrease in FMC time. Finally, a 5-minute decrease in the Door to ECG time can be associated with about a 5-minute decrease in FMC to Balloon time.

Facility C D2B (RQ3). This analysis of Door to balloon time utilized a sample stratified by facility (N = 153). The analysis resulted in a total of five regression models.

A complete list of the predictors and their associated variance can be found in Table 51. The first model was restricted to covariates in order to control for them in subsequent models. The covariates accounted for only 6% of the variance of Door to balloon time. The remaining models added the following predictors, respectively: Door to ECG time, Lifesaving measures, Prehospital STEMI activation, and Cardiologist arrival time. Together with the covariates these predictors accounted for over 63% of the variance of Door to balloon time at this facility.

Table 51. Variance accounted for by predictors of D2B at Facility C (RQ3).

Model	Variables added	Variance added	Total variance
Model 1	Covariates	6.0%	6.0%
Model 2	Door to ECG time	22.7%	28.7%
Model 3	Lifesaving measures	13.4%	42.1%
Model 4	Prehospital STEMI activation	9.8%	51.9%
Model 5	Cardiologist arrival time	11.3%	63.2%

Analysis of the B coefficients of model 5, as reported in Table 32, provides a more in-depth view of how the individual predictors directly impact Door to balloon times. The model coefficients, which were all found to be significant with p-values > .001, show us that 5-minute decrease in the Door to ECG time can be result in an almost 4-minute decrease in Door to Balloon time. The model also shows that lifesaving measures can increase Door to balloon time by over 22 minutes at this facility.

Conversely, the use of Prehospital STEMI activation can be associated with an over 15-minute reduction in Door to balloon time. Finally, a 5-minute reduction in Cardiologist arrival time has minimal impact resulting in an almost 2.5-minute reduction in D2B time.

Facility C FMC (RQ4). The analysis of First medical contact to balloon time utilized a stratified sample of 95 cases from this facility. This analysis resulted in a total of five regression models. A complete list of the predictors and their variances accounted for can be found in Table 52. The first model was restricted to the covariates in order to control for them in subsequent models. The covariates accounted for 4.1% of the variance of First medical contact to balloon time. Subsequently, models 2 through 5 added the following predictors, respectively: Cardiologist arrival time, Prehospital STEMI activation, EMS transport time, and Lifesaving measures. Together with the covariates these predictors accounted for over 74% of the variance of FMC to balloon times at this facility.

Table 52. Variance accounted for by predictors of FMC at Facility C (RQ4).

Model	Variables added	Variance added	Total variance
Model 1	Covariates	4.1%	4.1%
Model 2	Cardiologist arrival time	28.5%	32.6%
Model 3	Prehospital STEMI activation	17.2%	49.8%
Model 4	EMS transport time	17.6%	67.4%
Model 5	Lifesaving measures	7.3%	74.7%

Analysis of the B coefficients of the final model, as reported in Table 36, provides a more practical view of how the individual predictor impact FMC to balloon times. The model coefficients, which were all found to be significant with p-values < .001, indicate that a decrease of 5 minutes in Cardiologist arrival time would only result in a 2.4-minute reduction of FMC to balloon time. Subsequently, the use of Prehospital STEMI activation can result in an over 22-minute reduction in FMC to balloon time. However, a 5-minute decrease in the EMS transport time would correspond to a 4.2-minute reduction in FMC to balloon time. Finally, the model shows that the need for Lifesaving measure prior to PCI can increase FMC to balloon time by over 24 minutes at this facility.

Facility D D2B (RQ3). This analysis of Door to balloon time utilized a stratified sample of 130 cases from this facility. The analysis resulted in a total of five regression models. A complete list of the predictors and their variances can be found in Table 53. The first model was restricted to covariates in order to control for them in subsequent models. The covariates accounted for only 0.5% of the variance of Door to balloon time at this facility. The subsequent models added the following predictors, respectively: Door to ECG time, Cardiologist arrival time, Prehospital STEMI activation, and Cath lab team arrival time. Taken as a set, these predictors account for over 51% of the variance of Door to balloon time at this facility.

Table 53. Variance accounted for by predictors of D2B at Facility D (RQ3).

Model	Variables added	Variance added	Total variance
Model 1	Covariates	0.5%	0.5%
Model 2	Door to ECG time	28.3%	28.8%

Model 3	Cardiologist arrival time	17.2%	46.0%
Model 4	Prehospital STEMI activation	4.1%	50.1%
Model 5	Cath lab team arrival time	1.6%	51.7%

Analysis of the B coefficients of the complete model, as reported in Table 40, provides a more practical look at how the each of the individual predictors directly impacts Door to balloon times at this facility. The model coefficients, which were mostly found to be significant with p-values < .001, show us that 5-minute decrease in the Door to ECG time can be associated with an over 5-minute decrease in Door to Balloon time. The coefficient of Cardiologist arrival time shows that a decrease of 5 minutes would only result in a reduction of Door to balloon time by about 3 minutes. Furthermore, the use of Prehospital STEMI activation will result in an over 8-minute reduction in Door to balloon time. Finally, while the coefficient of Cath lab team arrival time was not statistically significant, it does indicate that a 5-minute decrease can be associated with a decrease in D2B time of only 1.2 minutes.

Facility D FMC (RQ4). The analysis of First medical contact to balloon time utilized a stratified sample (N = 75). This analysis resulted in a total of four regression models. A complete list of the predictors and their variance can be found in Table 54. The first model was restricted to the covariates in order to control for them in subsequent models. The covariates accounted for 1.4% of the variance of First medical contact to balloon time. The second model added the variable EMS transport time. This model accounted for 28.8% of the variance. The third model added the variable Cardiologist arrival time which accounted for an additional 27.3% of the variance. Finally, model four, which was found to be statistically significant, added the variable Door to ECG time accounting for and additional 11% of the variance. Together with the covariates these predictors account for over 67.1% of the variance in FMC times at this facility.

Table 54. Variance accounted for by predictors of FMC time at Facility D (RQ4).

Model	Variables added	Variance added	Total variance
Model 1	Covariates	1.4%	1.4%
Model 2	EMS transport time	27.4%	28.8%
Model 3	Cardiologist arrival time	27.3%	56.1%
Model 4	Door to ECG time	11.0%	67.1%

Analysis of the B coefficients of model 4, as reported in Table 44, allows for a more practical understanding of how impact of the individual predictors on the FMC to balloon times at this facility. The model coefficients, which were found to be significant with a p-value $< .001$, show us that if the EMS transport time were reduced by 5 minutes one could expect the FMC time to subsequently decrease by approximately 5.4 minutes. The coefficient of Cardiologist arrival time shows that a decrease of 5 minutes would likely result in a 4.9-minute reduction of FMC to balloon time. Finally, a 5-minute decrease in the Door to ECG time can be associated with a 6.5-minute decrease in FMC to Balloon time

Common predictors of D2B time between facilities

The four analyses of Door to balloon time at the individual facility level did show multiple predictors that were common among the facilities. The predictor Prehospital STEMI activation was the one of the predictors to be present in the final models of all four facilities. While this predictor accounted for a significant amount of the explained variance at Facility A Hospital, this was not the case at other facilities. The predictor Door to ECG time was also common to all four facility level models, accounting for a significant amount of explained variance in most. While there were only two predictors common to all four facilities, there were multiple predictors common to two or three out of the four facilities. Cardiologist arrival time was a predictor common to Facility A Hospital, Facility C, and Facility D. The predictors Lifesaving measures and Regular versus off hours were also common to three of the four facilities. The predictor Cath lab team arrival time was only present in half of models at the facility level. Surprisingly, the predictors Anatomical variances and Critical diagnostic exams were only significant in the Facility Analysis.

Common predictors of FMC to balloon time between facilities

The four analyses of First medical contact to balloon time at the individual facilities required stratified samples. These samples only contained those patients presenting via EMS. Therefore, it was necessary to remove the predictor Mode of arrival and introduce a new Predictor, EMS transport time. Even with these changes the models still had a significant number of predictors in common. As expected, the predictor EMS transport time was common to all four facilities' models and in each accounted for a significant portion of the explained variance. The predictors Cardiologist arrival time, Prehospital STEMI activation, and Lifesaving measures were all common to three of the four models at the facility level. It should also be noted that all of these predictors were also the most common predictors in the D2B models. The predictors Cath lab team arrival time and Door to ECG time were only present in half of the models. Finally, the predictor Door to first MD time was only found in the Facility A FMC model, however, it accounted for less than 1% of the total explained variance.

Hypothesis testing

The results of this study allow us to answer the research questions that guided this study. These research questions are:

1. Which process factor(s) has a statistically significant impact on the door to balloon time in patients presenting with a STEMI, while controlling for the factors of age, gender and history of coronary artery disease, and history of coronary artery bypass grafts?
2. Which process factor(s) has a statistically significant impact on the first medical contact to balloon time in patients presenting, via EMS, with a STEMI, while controlling for the factors of age, gender and history of coronary artery disease, and history of coronary artery bypass grafts?
3. Which process factor(s) has a statistically significant impact on the door to balloon time in patients presenting with a STEMI, at the level of each individual facility, while controlling for the factors of age, gender and history of coronary artery disease, and history of coronary artery bypass grafts?

4. Which process factor(s) has a statistically significant impact on the first medical contact to balloon time in patients presenting, via EMS, with a STEMI, at the level of each individual facility, while controlling for the factors of age, gender and history of coronary artery disease, and history of coronary artery bypass grafts?

It can be concluded that, with regards to the analysis of Door to balloon time, the regression model consisting of the following predictors; Prehospital STEMI activation, Cardiologist arrival time, Lifesaving measures, Door to ECG time, Regular versus off hours, and critical diagnostic exams answers research question one. These variables all had statistically significant impacts on Door to balloon time and taken as a set, account for nearly 50% of the variance.

In the analysis of First medical contact to balloon time it can be concluded that the regression model consisting of EMS transport time, Prehospital STEMI activation, Cardiologist arrival time, Lifesaving measures, Door to ECG time, Regular versus off hours, and Critical diagnostic exams answers research question number two. This model was found to be statistically significant and accounts for over almost 60% of the variance of First medical contact to balloon time. These results also showed that the variables Prehospital STEMI activation, Cardiologist arrival time, Lifesaving measures, and Door to ECG time accounted for significant amounts of variance in both analyses. Therefore, it can be concluded that these process factors play an integral part in the STEMI process and subsequently reperfusion times.

The results of this study provide evidence relevant to the third and fourth research questions as well as make conclusions regarding predictors of Door to balloon time and First medical contact to balloon time at the individual facility level. The analyses of Door to balloon time provided us with statistically significant regression models from each of the individual sites. The model from Facility A includes the predictors Prehospital STEMI activation, Cardiologist arrival time, Critical diagnostic exams, Door to ECG time, Anatomical variances, and Regular versus off hours. Together, these variables account for over 40% of the variance. The model from Facility B includes the predictors Door to ECG time, Regular vs. off hours, Lifesaving measures, Cath lab team arrival time, and Prehospital STEMI activation accounting for over 48% of the variance. The model from Facility C includes the predictors Door to ECG time, Lifesaving measures, Prehospital STEMI activation, and Cardiologist arrival time accounting for over 63% of the variance. Finally, the model from Facility D includes the predictors Door to ECG time, Cardiologist arrival time, Prehospital STEMI activation, and Cath lab team arrival time accounting for over 50% of the variance. Taken as a set the models provide evidence relevant to research question three.

The analyses of First medical contact to balloon time provides statistically significant regression models from each of the individual sites. The model from Facility A includes the predictors EMS transport time, Prehospital STEMI activation, Cardiologist arrival time, Lifesaving measures, Cath lab team arrival time, and Door to first MD time. Taken as a set these predictors account for over 50% of the variance. The model from Facility B includes the predictors EMS transport time, Lifesaving measures, Prehospital STEMI activation, Cath lab team arrival time, and Door to ECG time. This model accounts for over 50% of the variance. The model from Facility C includes the variables Cardiologist arrival time, Prehospital STEMI activation, EMS transport time, and Lifesaving measures. Together these variables account for over 70% of the variance. Finally, the model from Facility D includes the variables EMS transport time, Cardiologist arrival time, and Door to ECG time. This model accounts for over 60% of the variance. Together these models provide evidence relevant to research question four.

These results allow for further insights regarding the predictors. It is clear that some process factors do have significant impact on reperfusion times. The process factor Prehospital STEMI activation was present in 9 of the 10 statistically significant regression models in these analyses. This is clear evidence that Prehospital STEMI activation is significant to the STEMI process and as expected, the factor EMS transport time was a significant variable in all five models of First medical contact to balloon time. The predictors Cardiologist arrival time and Door to ECG time were also present in 8 of the 10 models. The predictor Lifesaving measures was present in 7 of the 10 models. Interestingly, factors such as Door to first MD time, Cath lab team arrival time, Critical diagnostic exams and Anatomical variances were rarely present in the models. This indicates that either these factors have very little overall impact on reperfusion times, or they were not significant enough in these analyses to demonstrate an impact. And yet some predictors such as Mode of arrival, Route of access, Prehospital ECG, and Door to triage time were not present in any of the models. This seems to show that these predictors have virtually no impact on reperfusion times.

Study contributions

This study built upon the current research regarding the identification and treatment of patient presenting with a STEMI, as well as filled gaps in the knowledge with regards to the analysis of multiple process factors together. By analyzing data from a number of process factors across four separate hospitals this study established which of these factors had the most significant impact on reperfusion times. The findings of this study confirm some aspects of previous research while contradicting others while establishing new findings that have the potential to significantly impact the STEMI programs in the Las Vegas area.

The results of this study clearly confirm the well-established importance of the use of prehospital ECG subsequently resulting in prehospital STEMI protocol activation. While the importance of prehospital STEMI activation has been established in other studies, when modeled with other process factors it remains statistically significant and accounts for the large amounts of the explained variance in nearly all models. This reinforces the need for a strong working relationship between the emergency departments and the ambulance crews. Providing consistent training in ECG interpretation for paramedics is crucial to the prehospital STEMI activation factor. This importance of this process factor may also be considered when electing to upgrade ambulance services with possible real-time ECG transmission abilities.

The results of this study establish the importance of the cardiologist arrival time to reperfusion times in the Las Vegas area. Cardiologist arrival time was statistically significant in a majority of the models and accounted for a significant amount of the explained variance. However, the Las Vegas healthcare market is unique in that few physicians are employed directly by hospitals. Instead, most physicians have joined private practices that contract with hospitals. This allows for the possibility that the cardiologist that is on STEMI call for a facility may not actually be present at that facility at all. Often times the on-call physician may even be on call for multiple facilities at once. This can lead to delays in cardiologist arrival time. The results of this study and the importance of Cardiologist arrival time in the individual facility level models are clear evidence that this needs further research.

The results of this study also confirmed the importance of door to ECG time to both D2B times and FMC times. Door to ECG time is tone of the he factors most directly involved with the identification of a STEMI. Door to ECG time was found to be statistically significant in nearly all of the models. It accounts for significantly more of the explained variance in the D2B models than in the FMC models. This finding is further confirmed by the inclusion of Door to ECG time metrics in the ACC accreditation process.

This study further confirmed the established importance of EMS transport time when examining the metric of FMC to balloon time. The results indicated that EMS transport time was a statistically significant process factor is every FMC model and accounted for the largest portion of the explained variance in all but one. These results again highlight the importance of strong working relationships between emergency departments and ambulance crews as well as the need for consist training and education regarding the treatment of STEMI patients for first responders.

The results of this study did contradict a popular and long held belief in a number of process factors considered important to reperfusion times. The results clearly showed that process factors such as Mode of arrival, Door to triage time, and Route of access had virtually no impact on reperfusion times in this study. These factors did not present in any of the statistical models. The process factors Door to first MD time, Anatomical variances, and critical diagnostic exams appeared in three or fewer models and accounted for minimal amounts of the explained variance when they did appear. Surprisingly, the process factor Cath lab team arrival time only appeared in four models and did not account for a significant amount of the explained variance in any of them. This is surprising due to the long-held belief that reducing the response time of the cath lab team significantly reduced reperfusion times (Bradley et al., 2006). This finding is likely due to the expanding use of prehospital STEMI activation, which activates the Cath lab team before the patient even arrives at the hospital. Finally, the process factor Regular versus off hours appeared in only four models and only accounted for a significant amount of variance in one. This contradicts previous research that has shown that patients presenting during regular hours had significantly reduces reperfusion times (Magid et al., 2005).

Implications for STEMI Programs

The results of this research may prove to be quite valuable for the STEMI programs in the Las Vegas area. While the overall statistical models of Door to balloon time and First medical contact to balloon time are useful, the models at the level of the individual facilities are of greater practical use. Presenting individualized facility results to administration, emergency department, and cardiac cath lab teams at each facility allows for the pinpointing the exact factors that have significant impact on their reperfusion times. This level of accuracy allows for direct changes to the individual facilities' STEMI processes. These results can also be presented to the EMS departments in order to inform them of the impact of their procedures with respect to reperfusion times.

While it is clear that some factors such as Anatomical variances and Lifesaving measures cannot be changed it is still beneficial to understand their impact on reperfusion times. Other factors such as Prehospital STEMI activation, Door to ECG time, Cardiologist arrival time, and Cath lab team arrival time can be changed. It is clear that Prehospital STEMI activation, Cardiologist arrival time, and Door to ECG time are major factors in the STEMI process. The results of these analyses indicate that it would be beneficial for the facilities to continue to work closely with the EMS departments in order to provide them with the tools and training to identify possible STEMI patients early and activate the STEMI protocol prior to arrival thereby reducing reperfusion times.

The results of this study could also influence hospital administrators to initiate their own internal analyses of reperfusion times in order to continue to refine their STEMI program and policies The focus on process factors can contribute to the development of a system, similar to the CMS core measures, at individual facilities. This type of system would allow for a more significant system of tracking factors affecting reperfusion times and increase the awareness of their impact. In the future this type of data collection and analysis system could easily be adapted to similar programs such as the treatment of patient with ischemic stroke, pulmonary embolism, or septic shock.

Limitations

A limitation to this research study was the general lack of participation among a significant portion of the hospitals in the Las Vegas area. A majority of facilities were unwilling to share their STEMI data, even for research purposes. This reluctance led to a smaller overall sample size due to participation by only four of the twelve facilities in Las Vegas. These four facilities were all from the same healthcare organization and were all classified as acute care hospitals with comparable bed counts. Unfortunately, with this limited sample is was not possible to analyze the effects of factors such as facility type and bed count on reperfusion times. These facilities being from the same healthcare organization also limited the generalizability of the results to other facilities and health care systems.

A second limitation to this study were the significant number of missing values present in the initial sample. This was likely due to changes in both the data collection procedures and the staff conducting the data collection. This limitation is common when using secondary data sources. In order to address this limitation, the primary investigator coordinated with the chest pain coordinators as well as the medical records departments at each of the facilities in order to attempt to recover some of the missing data. This process did recover a portion of the missing values; however, it remained necessary to exclude over 100 cases due to missing values.

Another limitation is due to the unique relationship between cardiologists and the hospitals in the Las Vegas area. Because the cardiologists in the Las Vegas area are considered outside contractors and not employees of the individual hospitals, it is necessary for each facility to negotiate contracts for STEMI call coverage. This unique relationship means that often the cardiologist that is on STEMI call is often not present at the facility and may even be performing a procedure at another facility. This limits the generalizability of the results to other facilities that have cardiologists employed at their facility.

A further limitation of this research study was that while the collected sample encompassed a three-year time period from Jan 2015 to Dec 2017, there remains the possibility that the participating facilities may have initiated performance improvement changes to their STEMI process that could not be adequately accounted for in the analyses.

Future Research

Future studies investigating the STEMI process are certainly warranted and recommended. A future study in the Las Vegas area with a larger sample size and encompassing a greater number of hospitals would be beneficial. A nationwide study conducted using data from the ACC database may also be useful. While the results of this current study do shed some light on which process factors have significant impact on reperfusion times, there still remains significant amounts of the variance of reperfusion times that have not yet been accounted for by the analyzed process factors. Future research would benefit from examining other factors such as facility type, age of the STEMI program, cardiologist experience and skill level, as well as staff composition and experience.

Summary

This study identified and discussed the seriousness of the condition ST-segment elevation myocardial infarction or STEMI and highlighted the importance reperfusion times to patients' overall outcomes. The purpose of this study was to examine and analyze the process factors involved with the identification and treatment of patients presenting with a STEMI and to develop a series of statistical models of the factors with the most significant impact on reperfusion times at both the overall and individual facility level.

The results of this study have established a series of statistically significant models of the predictors of reperfusion times at both the organizational and individual facility levels satisfying the research questions established for this study. One of the key takeaways of this study is the importance of timely identification of STEMI patients. While consistent with other research, the importance of timely identification is further demonstrated by the significance of both the predictors Prehospital STEMI activation and Door to ECG time in this study. Whether it be through EMS activating the STEMI protocol in route to the hospital or a short Door to ECG time for walk-in patients, it is clear that rapid identification of STEMI patients is crucial to reducing reperfusion times. Some models allow for estimates as high as a 22-minute reduction in Door to balloon times for STEMI patients when EMS utilized prehospital STEMI activation.

The predictor Cardiologist arrival time was another process factor found to be statistically significant in models at both the overall and individual facility levels. While it was present in multiple models, overall impact of cardiologist arrival time was relatively low with most models estimating that a 5-minute reduction would only reduce reperfusion time by roughly the same amount. However, in cases in which the cardiologist arrival time is significant higher this small impact on reperfusion times can grow. This can become especially worrisome in cases when the on-call cardiologist is delayed or at another facility. As expected, other process factors such as EMS transport time and Lifesaving measures were also shown to have significant impact on reperfusion times in most models.

Other key takeaways of this study are the process factors that were found to have minimal or no impact on reperfusion time. While it directly impacts Prehospital STEMI activation, the factors Prehospital ECG was determined to have virtually no impact on reperfusion times in this study. Other factors with no impact on reperfusion time in this study were Mode of arrival, Door to Triage time, and Route of access. The factors Door to first MD time, Anatomical variances, and Critical diagnostic exams were determined to have minimal impact on reperfusion times overall. These factors only appeared in a handful of models and accounted for very little of the explained variance. Most surprisingly, the Cath lab team arrival time was only significant in just under half of the models and did not account for a significant amount of the explained variance.

Overall, the goal of this study was to better understand how these factors together impacted reperfusion times and subsequently patient outcomes. The results of this study confirmed previous research and established a new understanding of some of these process factors and their impacts on reperfusion times. These results allow individual STEMI program coordinators to better understand which process factors should be focused on based on their facility specific data. Finally, this study has opened the door for subsequent research studies at the individual facility level as STEMI program performance improvement continues among the hospitals in the Las Vegas area.

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