EVALUATION OF A NEW EMERGENCY DEPARTMENT TRIAGE PROCESS ON
DOOR-TO-ECG TIME

by

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Abstract

**Background:** Acute coronary syndrome (ACS) including acute myocardial infarction (AMI) is one of the leading causes of morbidity and mortality in Canada, and commonly seen in the emergency department (ED). A 12-lead electrocardiogram (ECG) is the most important initial step in diagnosis and treatment of ACS patients. Best-practice guidelines recommend ECG acquisition within 10 minutes of ED arrival for all suspected ACS patients. However, many hospitals have been unsuccessful in achieving this quality benchmark. A new triage process, included a multi-pronged, interdisciplinary approach to obtaining an ECG prior to patients being registered, including educating staff, creating a 7-step process guide, and designating an ECG space. **Purpose:** To evaluate the effect of pre-registration ECGs for walk-in patients with suspected ACS, on door-to-ECG (D2ECG) time. **Method:** We used a retrospective, quasi-experimental design with a historical comparison group. Patients with suspected ACS not arriving via ambulance were included. Suspected cardiac arrhythmia patients were also included to analyze for possible untoward effects of the intervention. Data from two 9-month periods yielded a sample of 4115 (pre-implementation [group 1], n=2042; post-implementation [Group 2], n=2073), with the same proportion of suspected ACS patients in each group. Data on sex, age, time of arrival, chief complaint code and ECG time was retrieved from the hospital electronic database and analyzed. Mann-Whitney U test, Kruskal-Wallis test and hierarchical multiple linear regression were used for analysis. **Results:** Median D2ECG time was shorter for suspected ACS patients in group 2, Mdn=10 minutes (IQR, 7-21), than group 1 Mdn= 40 minutes (IQR, 28-59), p=0.00. D2ECG time among suspected cardiac arrhythmia patients was also shorter post-implementation, p=0.00. Multiple linear regression demonstrated that the new triage process was associated with an 81% reduction in D2ECG time. Older patients and women had
longer D2ECG times. **Conclusion:** Implementation of pre-registered ECGs is associated with an effective intervention in improving D2ECG time among suspected ACS patients in the ED.
Lay Summary

The goal of this study was to see if a new process would improve how quickly a patient with a possible heart attack would receive an ECG (heart tracing) after arriving in the emergency department. We measured the time from arrival to obtaining the ECG (door-to-ECG) before and after starting a new process for getting an ECG. This process involved getting the ECGs before the patient had been registered in the system. Also, staff were trained and a specific place for ECG testing was created. Patients who possibly had heart rhythm problems were also reviewed to see if the new process had any bad effects on other patients. Door-to-ECG time was better after starting the new process for both possible heart attack and heart rhythm patients. Older patients and women had longer door-to-ECG times.
Preface

This thesis is an original, unpublished product by Neda Khoshnood. The research study was conducted under the guidance of committee members: Dr. Martha Mackay (Supervisor), Dr. Susan Dahinten and Dr. Corinne Hohl. I conducted the background, literature review and all written chapters one to five. The methods and analysis chapters were written in collaboration with Dr. Mackay and Dr. Dahinten. All committee members reviewed and provided feedback on chapters one to five. This study received ethics approval from the University of British Columbia Research Ethics Board (certificate number H18-02958) and Vancouver Coastal Health Operational Approval (certificate number V18-02958).
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<tr>
<td>ACC/AHA</td>
<td>American College of Cardiology and American Heart Association</td>
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<td>ACS</td>
<td>Acute coronary syndrome</td>
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<tr>
<td>D2B</td>
<td>Door-to-Balloon</td>
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<td>D2ECG</td>
<td>Door-to-ECG</td>
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<td>ECG</td>
<td>Electrocardiogram</td>
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<td>ED</td>
<td>Emergency Department</td>
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<td>MI</td>
<td>Myocardial Infarction</td>
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<td>NSTEMI</td>
<td>Non-ST-elevation Myocardial Infarction</td>
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<tr>
<td>PCI</td>
<td>Percutaneous Coronary Intervention</td>
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<td>SPSS</td>
<td>Statistical Package for the Social Sciences</td>
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<tr>
<td>STEMI</td>
<td>ST-elevation Myocardial Infarction</td>
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<tr>
<td>VGH</td>
<td>Vancouver General Hospital</td>
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Chapter 1: Introduction

Acute coronary syndrome (ACS) is a high-risk clinical condition that requires rapid clinical assessment and interventions to improve patient outcomes. ACS, which includes acute myocardial infarction (both ST-elevation myocardial infarction [STEMI] and non-ST-elevation myocardial infarction [NSTEMI] and unstable angina, is one of the leading causes of morbidity and mortality across Canada and other developed countries (Teo, et al., 2014). In patients who are experiencing a STEMI, a 30-minute delay in treatment can increase the risk of mortality by 7.5% (Tra, van der Wulp, de Bruijne, & Wagner, 2015). There are several key components to achieving rapid reperfusion (restoration of blood flow to the myocardium, which is the goal of treatment for STEMI), including early identification of ACS symptoms and timely diagnosis (ACC/AHA, 2016). The standard tool for diagnosing myocardial infarction (MI) is the 12-lead electrocardiogram (ECG), a quick, definitive and non-invasive tool for patients experiencing chest pain or related symptoms (Yates & Hiestand, 2011). Joint clinical practice guidelines from the ACC/AHA (2009) specify that 12-lead ECG acquisition within 10 minutes of arrival to the emergency department (ED) for all suspected ACS patients is a best-practice goal for providing high quality care. Despite these guidelines, hospitals often do not achieve these targets (Yiadom et al, 2017; G. Wong, Personal Communication, March 2016; Atzema, Austin, Tu, & Schull, 2011). ED triage nurses are pivotal in achieving the recommendations set by the ACC/AHA, as it is they who assess the patient and initiate the process for timely and appropriate care and treatment (Arslanian-Engoren, 2009). From December 2015 to September 2016, the median door-to-ECG time was 32 minutes for “walk-in” STEMI patients at Vancouver General Hospital (G. Wong, personal communication, March 2017). To address this shortfall, Vancouver General Hospital (VGH) implemented a new process in October 2016 which included acquiring an ECG.
in a newly designated space before the patient had been registered in the hospital’s electronic patient information system. For the purposes of the paper, this novel process will be termed “pre-registration ECGs”.

Prior to the above changes, no diagnostic assessments could be obtained before the patient had been registered. The new triage process eliminated a number of steps required before an ECG could be obtained for high-risk patients. The effect of obtaining pre-registration ECGs on achieving the door-to-ECG (D2ECG) benchmark times had not been evaluated. Additionally, it was important to explore which patient factors were associated with D2ECG times for walk-in patients with suspected ACS. Lastly, it was valuable to consider any unintended effects of the pre-registration ECGs on other populations, such as non-ACS patients. Therefore, our study also examined the effect of the implementation of pre-registration ECGs on D2ECG time for walk-in patients with suspected cardiac arrhythmias to ensure no unintended delays occurred in other populations when suspected ACS patients were prioritized for ECG acquisition.

**Background**

More than 1.6 million Canadians suffer from cardiovascular disease, which accounts for approximately 500,000 ED visits annually (Wong, et al., 2015). Chest pain and other symptoms suggestive of ACS, such as shortness of breath, are the most common complaints of patients who visit an ED (Wong, et al., 2015). STEMI is diagnosed in approximately 33% of ACS patients and can be life-threatening unless timely interventions are instituted (Krumholz, et al., 2006; Fitchett, et al., 2011; Glickman, et al., 2012). These patients often suffer from complete coronary vessel occlusion caused by plaque rupture and activation of the coagulation cascade, restricting blood flow to the myocardium (Rivera-Bou, Cabañas & Villanueva, 2016). Studies have shown that delays between diagnosis and reperfusion of myocardium result in irreversible myocardial death,
which is strongly correlated with detrimental clinical outcomes, including re-infarction due to prolonged myocardial ischemia, stroke and death (Rivera-Bou, Cabañas & Villanueva, 2016; Guerchicoff, 2014).

In 1941, Bulmgart and colleagues established that the extent of myocardial infarction was related to the duration of coronary artery occlusion (Braunwald, 1993). Their open-artery theory set the foundation for current interventions and highlighted the importance of early reperfusion therapy for myocardial recovery (Braunwald, 1993) through percutaneous coronary intervention (PCI) or fibrinolytic therapy (Fitchett, et al., 2011). PCI is an intervention that treats complex coronary occlusions through intracoronary balloon inflation and usually insertion of a metal stent into the blocked vessels caused by atherosclerosis (Heart and Stroke Foundation of Canada, 2017). PCI was first introduced in 1977 and is the most effective intervention for STEMI patients when 1) the center has access to this technology, b) it can be delivered in a timely manner and 3) is not otherwise contraindicated (Switaj, Christensen, & Brewer, 2017).

Fibrinolytic therapy is a treatment option when PCI is not available or contraindicated (Switaj, Christensen, & Brewer, 2017). Fibrinolytic agents were first discovered in 1933 and aid in the breakdown of fibrin in clots (Rivera-Bou, Cabañas & Villanueva, 2016). In 1986 streptokinase was recognized as an effective treatment for dissolving intracoronary thrombus in STEMI patients (Rivera-Bou, Cabañas & Villanueva, 2016). While evidence favors PCI for STEMI patients when appropriate, timely intervention is the main challenge in achieving optimal outcomes (Kumar & Cannon, 2009; Keeley, Boura, & Grines, 2003). The American College of Cardiology and American Heart Association (ACC/AHA) recommend that the time from hospital arrival to inflation of balloon in the coronary artery (door-to-balloon (D2B)) not exceed 90 minutes and arrival to injection of fibrinolytic therapy not exceed 30 minutes (Krumholz, et
Achieving timely reperfusion is key to preserving left ventricular function, reducing length of stay in hospital, decreasing hospital readmission rates and improving quality of life (De Boer & Zijlstra, 2015).

In an effort to reduce treatment delays and improve quality of care for STEMI patients, the ACC, AHA, and partnering international agencies initiated the door-to-balloon (D2B) Alliance in 2006 (Krumholz, et al., 2008). The term D2B is defined as the time between hospital arrival and delivery of reperfusion therapy by PCI. This procedure involves using a balloon-tipped catheter to enlarge the narrowed coronary artery and achieve reperfusion (Krumholz, et al., 2008). A delay in this process is associated with an increased risk of mortality (Krumholz, et al., 2008). Rapid D2ECG time is an important part of achieving timely revascularization, as a definitive diagnosis of STEMI is necessary before reperfusion therapies can be considered.

The Alliance established D2B time of 90 minutes or less as the gold standard for participating hospitals and achieved their target goal by 2008 (Krumholz, et al., 2008). In 2007, lessons adapted from the D2B Alliance helped launch the AHA “Mission: Lifeline” to improve health care responses to STEMI patients (O’Gara, et al., 2013).

Unfortunately, in spite of efforts such as “Mission: Lifeline”, approximately 12% of ACS patients die due to inadequate and inefficient treatments that do not follow best-practice guidelines (Graff, Palmer, Lamonica, & Wolf, 2000). Studies suggest that approximately one-hour after onset of ACS symptoms the opportunity to treat patients effectively becomes limited (Graff et al., 2000). The first step in achieving this time-sensitive outcome is the immediate identification of ACS symptoms and obtaining a 12-lead ECG (Purim-Shem-Tov et al., 2007). Several factors lead to delays in ECG acquisition and prolong initiation of reperfusion therapies.
including ED crowding, atypical symptoms, and inefficient triage processes (Purim-Shem-Tov, Rumoro, Veloso, & Zettinger, 2007). The triage process will be the focus of the study.

A 12-lead ECG is a rapid test, necessary to differentiate a STEMI from other ACS presentations, so that appropriate and timely interventions may be initiated (Yates & Hiestand, 2011). This test must be obtained as soon as possible after initial medical contact, either by trained paramedics during pre-hospital care or in the ED if the patient does not enter the system via ambulance. Once an ECG is obtained, rapid interpretation by a professional trained to identify STEMI allows for immediate access to reperfusion therapy (ACC/AHA, 2016). While non-modifiable comorbidities such as heart failure and diabetes increase the risk of death in STEMI patients, the time to reperfusion is a factor that health care professionals can modify (Tra, van der Wulp, de Bruijne, & Wagner, 2015).

Research has shown that timely ECG acquisition is the most important determinant in quickly and correctly identifying high-risk ACS patients, and should be obtained within 10 minutes of ED arrival (Yates & Hiestand, 2011; Purim-Shem-Tov, Rumoro, Veloso, & Zettinger, 2007). This recommended D2ECG target time is a part of a larger systematic guideline for improving door-to-balloon or door-to-needle time for STEMI patients (ACC/AHA, 2016). Early identification of high-risk patients by prompt ECG acquisition and interpretation allows for life-saving treatments such as PCI or fibrinolytic therapy (Purim-Shem-Tov, Rumoro, Veloso, & Zettinger, 2007). However, despite the overwhelming evidence for the recommended target times for ECG acquisition, a delay in performance continues to exist among these patients across hospitals (Yiadom et al, 2017; Atzema, Austin, Tu, & Schull, 2011). Failure to achieve timely D2ECG acquisition is a concern for large urban tertiary centers in Canada, as reported by
Vancouver General Hospital in 2015 and 2016 (G. Wong, Personal Communication, March 2016). Thus, an opportunity exists to evaluate strategies used to improve D2ECG times.

Studies have shown that pre-hospital ECG acquisition by emergency medical service (EMS) providers reduces time-to-reperfusion therapy among STEMI patients (Curtis, et al., 2006). Pre-hospital ECG acquisition allows ED physicians to promptly assess the 12-lead ECG before the patient has arrived in the ED, correctly diagnose STEMI and initiate STEMI protocols in their region (Curtis, et al., 2006). It has been suggested that timely reperfusion therapy can only be achieved when a pre-hospital ECG system is combined with a systems approach to activating a STEMI protocol (Swor, Hegerberg, McHugh-McNally, Goldstein & McEachin, 2006).

However, not all EMS responders are able to acquire a 12-lead ECG in the field. In addition, STEMI patients who self-present experience longer D2ECG times compared to those transported by EMS (Coyne, et al., 2015). Consequently, suspected ACS patients arriving with basic paramedic EMS crews or “walk-in” patients highlight the need for an effective strategy to obtain timely 12-lead ECGs in EDs (Morrison, Brooks, Sawadsky, McDonald, & Verbeek, 2006). The study focused on walk-in patients.

Undoubtedly, the early identification of ACS patients by frontline ED teams improves patient outcomes and survival. Research has shown that nurses depend on their past clinical experience and knowledge to make accurate triage decisions (Arslanian-Engoren, 2009). The literature suggests that nurses use limited physiological data such as vital signs when determining the urgency of patients, which contributes to inconsistent assessment practices (Arslanian-Engoren, 2009). Several factors influence triage nurses’ decisions about the urgency of potential ACS patients including the patient’s chief complaint, clinical presentation, medical
history, mode of arrival, and vital signs (Arslanian-Engoren, 2009). Additionally, nurses’ own attitudes, beliefs, knowledge base and experience in the ED also influence their decision-making (Arslanian-Engoren, 2009).

While triage nurses’ professional responsibility and intention may be for potential ACS patients to receive a timely ECG, prompt evaluation and appropriate intervention, inconsistencies in assessment skills, related to the years of experience and educational training, may create a gap in clinical practice. Although these factors will not be investigated in this study, this insight may help develop future interventions aimed at producing standardized procedures to improve D2ECG times (Arslanian-Engoren, 2009).

Coyne and colleagues (2015) found that one innovative and cost-effective method for improving D2ECG time is a change in the ED triage process for potential ACS patients. The authors developed a chief complaint-based cardiac triage process which more efficiently evaluated potential ACS patients (Coyne, et al., 2015). To date, such changes in ED cardiac triage have only been studied in smaller, lower-volume hospitals. The authors have recommended evaluation of these changes in larger urban teaching centers.

**Problem Statement**

Timely D2ECG acquisition has been identified as the pivotal initial assessment for suspected ACS patients to achieve timely interventions, reperfusion and patient outcomes. However, hospitals are challenged to achieve this best-practice performance indicator. Thus, there was a need to evaluate the effect of pre-registration ECGs on D2ECG times. This evaluation also provided an opportunity to identify other factors that may influence D2ECG times, such as patient characteristics and ED arrival time.
**Research Purpose**

The purpose of this study was to investigate the effect of pre-registration ECGs for walk-in patients with suspected ACS, on D2ECG time.

**Research Questions**

The study was guided by the following questions:

1. What patient factors are associated with D2ECG times for walk-in patients with suspected ACS?

2. What is the effect of the implementation of pre-registration ECGs on D2ECG time for walk-in patients with suspected ACS?

3. What is the effect of the implementation of pre-registration ECGs on D2ECG time for walk-in patients with suspected cardiac arrhythmias?

4. What is the effect of the implementation of pre-registration ECGs on D2ECG time for walk-in patients with suspected ACS, after accounting for patient characteristics?
Chapter 2: Literature Review

Search Strategy

This review of the literature provides context for the proposed study by exploring the various factors that influence door-to-ECG (D2ECG) times among patients with suspected ACS and interventions that have been tested to improve D2ECG. The first section will review studies that explored factors that may influence D2ECG times. The second section will highlight interventions aimed to improve D2ECG times. The search strategy used to explore the first two sections is described below. Finally, through the critical review of the literature gaps in knowledge, which provide rationale for the proposed study design, will be identified.

The literature searches were conducted by using electronic databases MEDLINE (via Ovid), and CINAHL. To initially search for research articles, the terms chest pain or acute coronary syndrome, and emergency department or triage, and electrocardiogram or electrocardiography or ECG were explored and combined, which resulted in 2,214 articles dated from 1980 to 2019. To ensure all relevant articles were captured and to refine the search the terms door-to-ECG, door-to-EKG, door-to-electrocardiogram or door-to-electrocardiography were searched using the Boolean method to further produce more relevant results which yielded 57 articles. The terms were search in MEDLINE (via Ovid) which returned 57 articles and in CINAHL which returned 39 articles. Of the combined 96 articles in both databases, 38 articles were duplicates, 30 did not study the primary outcome of interest, and 2 were not in English. Thus, after the above exclusions, 26 quantitative research reports were selected for an in-depth review for this portion of the literature review. These final set of articles were published from 2006 to 2019. These 26 articles were divided into two subgroups based on study design; observational studies (n=12) and those testing an intervention (n=14) illustrated by Table 1.
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**Observational Studies: Factors that Influence D2ECG Times**

Twelve observation studies were reviewed to better understand factors that may influence D2ECG time. The studies used an observational design, eight were retrospective (Atzema et al., 2009; Yates et al., 2011; Atzema et al., 2011; Spence et al., 2012; Na et al., 2014; Dasari et al., 2014; Mazurek et al., 2017; and Nonnenmacher et al., 2018) and four were prospective observational studies (Diercks et al., 2006; Pearlman et al., 2008; Pelletier et al., 2014; and Mackay et al., 2018). The main objective of the 12 observational studies was to determine which factors have previously been shown to affect D2ECG times in the ED, sample size ranged from 217 to 43,242 patients.

Five articles’ main outcome was D2ECG times (Diercks et al., 2006; Pearlman et al., 2008; Yates et al., 2011; Spence et al., 2012; and Mackay et al., 2018), whereas seven articles’ primary outcome was performance measures and patient outcome, where D2ECG time was embedded in the outcome measure (Atzema et al., 2009; Atzema et al., 2011; Pelletier et al., 2014;
Na et al, 2014; Dasari et al, 2014; Mazurek et al, 2017; and Nonnenmacher et al, 2018). There were four Canadian (Atzema et al., 2009; Atzema et al., 2011; Mazurek et al., 2017; & Mackay et al., 2018), four American studies (Yates et al., 2011; Spence et al., 2012; Pearlman et al., 2008; & Dasari et al., 2014), two international studies (Na et al., 2014 and Nonnenmacher et al., 2018) and two studies were conducted across different countries which included Canada and USA (Diercks et al., 2006 and Pelletier et al., 2014). Five studies were conducted in a single site, a large urban hospital with sample sizes ranging from 197 to 1196 (Pearlman et al., 2008; Yates et al., 2011; Spence et al., 2012; Mazurek et al., 2017; & Nonnenmacher et al., 2018). Seven studies used a multicenter approach with sample sizes ranging from 448 to 43,242 (Diercks et al., 2006; Atzema et al., 2009; Atzema et al., 2011; Pelletier et al., 2014; Na et al., 2014; Dasari et al., 2014; & Mackay et al., 2018).

**Sociodemographic Factors Affecting D2ECG Time.** Six studies aimed to evaluate the effects of age, sex, and/or race/ethnicity on D2ECG times among patients with suspected ACS (Diercks et al, 2006; Pearlman et al, 2008; Yates et al, 2011; Spence et al, 2012; Pelletier et al, 2014; and Mackay et al, 2018). Four indicated a delay in ECG acquisition among women (Diercks et al, 2006; Pearlman et al, 2008; Na et al, 2014 and Mackay et al, 2018) and two identified younger age as being associated with greater D2ECG times (Diercks et al, 2006; and Pearlman et al, 2008). Na and colleagues (2014) identified that female STEMI patients presenting with non-chest pain symptoms are subject to delayed D2ECG times. Three studies found no statistical significance of race as a factor related to D2ECG times (Pearlman et al, 2008; Yates et al, 2011; and Mackay et al, 2018). Factors such as anxiety, risk factors for cardiovascular disease, low-priority triage score and the absence of chest pain have also been
found to be related to prolonged D2ECG times (Pelletier et al., 2014; Na et al., 2014; and Nonnenmacher et al., 2018).

**Organizational and System Factors Affecting D2ECG Time.** Four studies examined the effects of organizational and system factors that may influence D2ECG times. These included patient volumes, time of day and triage processes (Atzema et al., 2009; Dasari et al., 2014; Mazurek et al., 2017; and Nonnenmacher et al., 2018). Two studies identified that ED volumes and arrival times did not contribute to delayed ECG acquisitions (Dasari et al., 2014; and Mazurek et al., 2017). Several studies found that incorrectly assigning low priority scores to potential ACS patients contributed to a delay in ECG times (Atzema et al., 2009; Atzema et al., 2011; and Nonnenmacher et al., 2018). For example, Atzema and colleagues (2011) determined that a documented history of depression was associated with assigning lower priority triage scores, and was associated with delayed ECG acquisition among patients diagnosed with acute myocardial infarction.

**Interventional Studies: Interventions to Improve D2ECG Times.** The main objective of these 14 studies was to evaluate the effects of interventions on D2ECG time for suspected ACS patients in the ED. All studies used quasi-experimental research designs to create comparison groups, but were not randomized, sample sizes ranging considerably from 72 to 11,518. Eight teams employed a non-equivalent control group, pretest-post-test design while Purim-Shem-Tov et al. (2007) utilized a non-equivalent control groups, post-test only design (Purim-Shem-Tov et al., 2007; Phelan et al., 2009; Takakuwa et al., 2009; Ballard et al., 2011; Sprockel et al., 2015; Coyne et al., 2015; Keats et al., 2018; & Stanfield, 2018). Six of the studies used varying experimental prospective and retrospective cohort design (Glickman et al., 2010; Prachanukool et al., 2016; Yiadom et al., 2017; Keats et al., 2018; de Barros E Silva et al., 2018; Isono et al.,
Seven studies evaluated multiple outcomes, including D2B time (Takakuwa et al., 2009; Glickman et al., 2010; Coyne et al., 2015; Keats et al., 2018; de Barros E Silva et al., 2018; Isono et al., 2018; and O’Donnell et al., 2019).

**Categories of Interventions Used for Improving D2ECG Times.** These interventions can be categorized into 3 different groups: a change in ED triage process, the addition of trained personnel, or the development of educational criteria or tools.

Seven studies evaluated the implementation of a triage process (Phelan et al., 2009; Takakuwa et al., 2009; Glickman et al., 2010; Coyne et al., 2015; Keats et al., 2018; de Barros E Silva et al., 2018; & Isono et al., 2018). The seven studies that evaluated the implementation a new triage process all used a multifaceted approach, which included educating and training nurses, physicians and ECG technicians for obtaining ECGs, improving patient registration process, assigning a designated ECG space at triage and properly maintaining the ECG equipment. Specifically, these multidisciplinary, quality improvement approaches included active participation by cardiology technicians, who played a pivotal role in achieving ECG target times by being more accessible and accountable. Continuous feedback and staff support and education was also a part of these new triage processes, though improvement of D2ECG time may be related to a Hawthorne effect.

Three studies investigated the effects of an additional trained personnel on D2ECG times in the ED (Purim-Shem-Tov et al., 2007; Sprockel et al., 2015; & Stanfield, 2018). Purim-Shem-Tov and colleagues (2007) studied the use of a trained ECG “greeter”. The ECG greeter worked rotating shifts throughout a one-month period and conducted ECGs for patients meeting study criteria (Purim-Shem-Tov et al., 2007). The goal of the greeter was to rapidly identifying patients requiring a timely ECG (stable patients) and obtaining an ECG for those stable patients (n=40) or
alerting the triage nurse (unstable patients). Greeter directed ECG times (n=40) were less than non-greeter directed ECGs (n=86). Given the small sample size, evening and night shift D2ECG times were not statistically significant while the trends indicated a decreased D2ECG time with greeter directed ECG. Sprockel and colleagues (2015) designated an electrocardiogram machine and a nurse at triage who was dedicated to obtaining ECGs for chest pain triaged patients, the authors’ intervention were found to be statistically significant. The study conducted by Stanfleid (2018) also implemented the “first-nurse” role, which was a designated ED nurse dedicated to identifying ACS patients and achieving timely ECG. Monthly D2ECG time trends indicated improvement post-intervention while the results did not achieve statistically significance.

Four studies examined the effects of implementing only ACS screening criteria or tool in an effort to improve D2ECG times (Ballard et al., 2011; Prachanukool et al., 2016; Yiadom et al., 2017; & O’Donnell et al., 2019). These screening tools were designed to rapidly and accurately identify ACS patients to achieve timely ECG. Ballard and colleagues (2011) examined the effects of a chest pain mnemonic (CPM) as a teaching tool for nurses to reduce D2ECG times for suspected acute myocardial infarct patients (Ballard et al., 2011). D2ECG times were improved post-CPM education, but the results were not found to be statistically significant. Similarly, Prachanukool and colleagues (2016) created an acute chest pain fast track (ACPFT) guideline in an effort to accurately and promptly identify ACS patients; the authors found that 57% of patients with acute chest pain were enrolled in the ACPFT guidelines. Yiadom and colleagues explored the effectiveness of their STEMI identification tool across seven EDs by calculating missed case rate (MCR). The authors concluded that while STEMI screening tools are effective to accurately identifying these high-risk patients, missed cases are still prevalent across EDs and there is a continued need for improving STEMI identification. Uniquely, O’Donnell and
colleagues (2019) developed a scoring system on an Android tablet to clinically predict ACS patients and expedite timely ECGs as an effective, easy tool, which resulted in statistically significantly improved D2ECG times.

**Other Factors Associated with D2ECG Times.** Of the 14 interventional studies, only four evaluated D2ECG times after controlling for factors such as age, sex, race/ethnicity, arrival time, mode of arrival and triage classification (Takakuwa et al., 2009; Glickman et al., 2010; Ballard et al., 2011; & Keats et al., 2018). Takakuwa and colleagues (2009) adjusted for age, sex, race, arrival time, arrival mode, and triage classification, and found that patients were 3.9 times more likely to receive an ECG within 10 minutes or less post-intervention. Conversely, Ballard et al. (2011) and Keats et al. (2018) found that women had longer delays in ECG acquisition post-intervention. In contrast, Glickman and colleagues (2010) reported improved D2ECG times among women, minorities and the elderly associated with the implementation of a STEMI regionalization program, which included education and training.

**Identified Gaps and Chapter Summary**

Consistently in the reviewed literature is a continuing need for achieving best-practice guidelines for obtaining D2ECG times less than 10 minutes, standards set forth by the ACC/AHA. There are diverse results from research evaluating sociodemographic and organizational/system predictor variables and their effects on D2ECG time which therefore leaves a gap in the literature. The results found in the reviewed body of literature for interventional studies were also varied. Overall, it suggests that interventions involving a multifaceted approach for implementing a new triage process, including educational support for frontline staff, improving the patient registration process and designating an ECG location were statistically and clinically effective. In contrast, interventions involving the addition of a
designated ECG technician at triage or screening tools for triage nurses, though limited, were not statistically significant. These mixed results warrant further research on interventions to improve D2ECG time.

The duration the interventions varied from 3 weeks to 18 months across all studies, and sustainability of these interventions was not evaluated. However, it is unknown whether continued educational support and feedback would equate to success and adherence to best-practice guidelines. Also, few interventional studies have actually incorporated sociodemographic or system factors into their statistical analysis. Given the facts that 1) benefits of the interventions varied by subgroup characteristics and 2) the number of robust studies supporting these practices was small, there is a gap in the current literature and which merits further exploration of these potential moderating effects. The impact of a change in triage process allowing technicians to obtain ECGs prior to patients being registered, called “unregistered ECGs”, has not been studied. This proposed strategy may be the first step towards quickly and efficiently obtaining ECGs.
Chapter 3: Methods

This chapter outlines the proposed design and methods for our study including the study setting, patient sampling, data collection, data analysis, and ethical considerations of our work. The primary purpose was to examine the effects of pre-registration ECGs on D2ECG time among walk-in patients with suspected ACS. The first research question explored which patient factors were associated with D2ECG times for walk-in patients with suspected ACS. The second research question explored the effect of the implementation of pre-registration ECGs on D2ECG time for walk-in patients with suspected ACS patients. Question 3 explored the effect of the implementation of pre-registration ECGs on D2ECG time for walk-in patients with suspected cardiac arrhythmias. The fourth research question investigated the effect of the implementation of pre-registration ECGs on D2ECG time for walk-in patients with suspected ACS, after accounting for patient characteristics.

Research Design

The proposed study employed a retrospective, quasi-experimental design using a historical comparison group (Polit & Beck, 2012). The study compared data for the dependent variable, D2ECG time, from two time periods: nine months before implementation of the new triage process and nine months post-implementation. This type of design is useful when the focus of the research question is on change. Because this design did not include random allocation to treatment groups, it was important to control for variables such as sex, age, time of arrival, chief compliant triage code, to account for confounding effects (Polit & Beck, 2012).

Ethical Considerations
University of British Columbia Clinical Research Ethics Board approval was obtained as well as Vancouver Coastal Health Operational approval. I removed patient identifiers as soon as possible after data collection was complete and study identification numbers were assigned to each subject. All documents and data were encrypted and stored on a password-protected computer that only the study team had access to.

**Study Setting, Study Period and Sampling Strategy**

This study was conducted in an urban, tertiary care, university-affiliated hospital. The ED sees over 93,000 patient-visits annually (VGH & UBC Foundation, 2014). The study period was defined as the implementation phase: pre-implementation phase January 01, 2016 and September 30, 2016 (group 1) and post-implementation phase January 01, 2017 and September 30, 2017 (group 2). This study period was selected based on the intervention implementation date of October 2016. We designated January 1, 2017 as the beginning of the post-implementation phase to allow for a four-month transition period for staff to adapt to the new process.

In an effort to enhance this study’s internal validity, we made an effort to ensure that the eligibility criteria and selected sample mirrored the population of interest (Polit & Beck, 2012). Therefore, included patients met the following inclusion criteria for research Questions 1, 2 and 4:

- Walk-in patients (defined as arriving by any means other than ambulance) to VGH ED
- Aged 30 years and older
- Chief complaint of chest pain (with the associated cardiac-related triage codes for chest pain or cardiac arrhythmia as described below).
The age criterion was selected given the understanding that age positively influences the probability of myocardial infarction. This is related to the ongoing process of plaque formation in the coronary arteries over an individual’s lifetime, which often results in an acute ischemic event (Kumar, & Cannon, 2009). While the literature suggests that the prevalence of myocardial infarction increases after the age of 45, in more recent years the incidence among younger adults is increasing due to the increased prevalence of contributing risk factors such as smoking, obesity and glucose intolerance (Kytö, et al., 2014; Yiadom, et al., 2017; Yunyun, et al., 2009).

Several codes were used to classify patients who report chest pain at triage, which were recorded in the hospital’s electronic system, PCIS. For the purpose of the proposed study, codes were selected which would capture the patients with the highest likelihood of ACS (AHA, 2017; Kumar et al., 2009).

To answer Questions 1, 2, and 4 these codes included:

- CV020  Chest Pain + severe respiratory distress
- CV021  Chest Pain + severe hypotension or shock
- CV022  Chest Pain, cardiac features
- CV027  Chest Pain + moderate respiratory distress
- CV028  Chest Pain + moderate hemodynamic compromise
- CV029  Chest Pain, resolved, significant cardiac history

To answer research Question 3, patients must have met all of the following inclusion and exclusion criteria as mentioned above, but with different chief-complaint codes.

Chief complaint related to cardiac arrhythmia as reflected in the following triage codes:

- CV053  Dysrhythmia/palpitations, severe hypotension or shock
- CV051  Dysrhythmia/palpitations, abnormal vitals
- CV052  Dysrhythmia/palpitations, normal vitals
- CV054  Palpitations, firing of internal defibrillator
- CV055  Palpitations, resolved

The exclusion criterion was arrival via ambulance or having an infield ECG by a trained paramedic team.
Designing, Adopting and Implementing Pre-Registration ECGs

Vancouver Coastal Health (VCH) recognized D2ECG times as a key quality indicator and thus started collecting data on this vital marker in 2007 (H. Lindsay, personal communication, June 2018). In 2014, Vancouver General Hospital (VGH) was identified as having the longest D2ECG times in the region. In 2016, the VGH ED Quality Council devised a way to achieve best-practice guidelines that involved changes to ED triage nurses’, physicians’, registration clerks’ and cardiology technicians’ clinical practice. The cardiology department at VGH was also consulted to help implement this new process. Collectively, they identified two barriers: the lack of a designated space for obtaining ECGs and the practice of completing patient registration prior to ordering an ECG. In October 2016, the Council developed a new triage process for “unregistered ECGs” and designated a space in the triage area to obtain ECGs for unregistered patients. A one-page guideline was created and posted by the triage window to help guide and remind triage nurses of the new process. The ED educator reinforced this new process in routine morning triage huddles for several weeks, and by providing supportive education to the ECG technicians with these new changes. Staffing levels were not changed or modified due to this new triage process. Posters, emails, and face-to-face reinforcement were provided to all stakeholders to promote the new ECG process (H. Lindsay, personal communication, June 2018).

Old Triage Process versus the New Triage Process

Table 2 describes the original five-step triage process (pre-intervention) for walk-in patients (defined as arriving to the ED by any means other than ambulance) with suspected ACS: and compares it with the new triage process, which incorporates “unregistered ECGs”, presented
as a seven-step process (Table 2). The new standardized triage process was implemented without hiring additional staff or adding technical support.

Table 2.

<table>
<thead>
<tr>
<th>Old Triage Process</th>
<th>New Triage Process</th>
</tr>
</thead>
<tbody>
<tr>
<td>(1) A walk-in patient presents to triage with chest pain or any signs of ACS; the</td>
<td>(1) A walk-in patient presents to triage with chest pain or any signs of ACS, as</td>
</tr>
<tr>
<td>triage nurse ascertains the patient’s chief complaint at the triage window, enters</td>
<td>determined by the triage nurse through clinical reasoning.</td>
</tr>
<tr>
<td>it into the computer and places the patient’s chart in the “VGH not triaged (VNT)”</td>
<td></td>
</tr>
<tr>
<td>bin.</td>
<td></td>
</tr>
<tr>
<td>(2) Another triage nurse selects patient charts from the VNT bin, based on their</td>
<td>(2) The triage nurse enters the patient in the computer as “VGH Not Triaged” then</td>
</tr>
<tr>
<td>arrival time and clinical presentation (e.g., if the patient appeared unwell (as</td>
<td>prints and attaches the patient’s label to the nursing notes.</td>
</tr>
<tr>
<td>judged by the triage nurse) then their chart would be placed on top of the pile.</td>
<td></td>
</tr>
<tr>
<td>(3) The triage nurse calls out the patient’s name (who would be sitting in the</td>
<td>(3) The triage nurse walks the patient to the ECG stretcher and assists the patient</td>
</tr>
<tr>
<td>waiting room) to collect further information such as vital signs and history.</td>
<td>to sit on the bed.</td>
</tr>
<tr>
<td>(4) The patient is moved to the registration counter while the triage nurse enters</td>
<td>(4) The ECG technician is notified by overhead page “stat unregistered ECG at</td>
</tr>
<tr>
<td>the ECG order into the clinical information system.</td>
<td>triage in the ECG stretcher.”</td>
</tr>
<tr>
<td>(5) The triage nurse notifies the ECG technician (pager, overhead page) and the</td>
<td>(5) The ECG technician obtains an ECG.</td>
</tr>
<tr>
<td>ECG technician makes a clinical judgment about the priority of the request.</td>
<td></td>
</tr>
<tr>
<td>(6) The ECG technician obtained an ECG.</td>
<td></td>
</tr>
<tr>
<td></td>
<td>(6) If the ECG demonstrates any ST-segment changes, the patient is taken to a</td>
</tr>
<tr>
<td></td>
<td>care space for bedside triage as directed by charge/triage nurse.</td>
</tr>
<tr>
<td></td>
<td>(7) If the ECG is normal, the technician directs the patient back to the waiting</td>
</tr>
<tr>
<td></td>
<td>room and puts the documentation into a pile for the regular triage and registration process</td>
</tr>
</tbody>
</table>
Source of and Access to Data

The study received approval from the UBC Clinical Research Ethics Board. Following ethics and operational approvals, a request for the specific clinical data on patients fulfilling the inclusion criteria was made to the Vancouver Coastal Health Data Release Management Office. The resultant data file was stored in a password-protected file on a hospital network computer stored in a locked office at VGH. The researcher removed patient identifiers such as Medical Record Number (MRN) and date of birth (DOB) from the file after the necessary data were obtained. The original file with patients’ identifiers was stored separately, in a password-protected file.

Measures

The dependent variable for this study was D2ECG time, measured in minutes. D2ECG time was defined as the interval from ED arrival until the time at which the first ECG was obtained. The time of ECG acquisition was captured by the Marquette Universal System of Electrocardiography (MUSE). The ED arrival time was defined as first documented time of the patients’ arrival at the triage counter. This was captured as an electronic time stamp in the Patient Care Information System (PCIS). The D2ECG time variable was created and calculated from these two values.

The independent variable was the new triage process and was treated as a dichotomous variable: pre-implementation phase (Group 1) versus post-implementation phase (Group 2).

The co-variates that were examined in this analysis included patient age, sex, arrival time, and chief complaint; this information was collected electronically through PCIS.

Power Analysis
A power analysis was conducted to inform the sample size, thereby reducing the risk of a Type II error and strengthening the statistical conclusion validity (Polit & Beck, 2012). For a medium effect size using the Mann-Whitney U, two-tailed test, the sample size was determined to be 134, according to the G* Power analysis for Mann-Whitney U test, with power 1-beta=0.80, alpha= 0.05, and medium effect size (0.5) (Faul, Erdfelder, Buchner & Lang, 2008). Similarly, for a small effect size the sample size was determined to be 824, with power 1- beta = 0.08, alpha = 0.05, and small effect size (0.2) (Faul, Erdfelder, Buchner & Lang, 2008). We expected a small effect size; thus, we aimed to obtain a sample size of 824.

Small sample sizes can be especially concerning when using multiple regression which was undertaken in this study. To ensure an adequate sample size was achieved, the Tabachnick and Fidell equation: N > 50 +8(number of predictor variables: age, sex, chief complaint, arrival time, implementation phase [intervention]) was used (Polit & Beck, 2012). We thus determined the recommended minimum sample size for a multiple regression with 5 predictor variables was 90.

Data Analysis

Statistical Package for the Social Sciences (SPSS) software, version 24 (IBM, United States) was used for all analyses.

Descriptive Statistics. Descriptive statistics (frequencies and measures of central tendency appropriate to the distribution of data) were used to describe the sample. Bivariate statistics, including the chi-square and t- tests were used to compare clinical and demographic characteristics of the pre- and post-implementation phases among suspected ACS patients and suspected cardiac arrhythmia patients.
**Mann-Whitney U Test and Kruskal-Wallis Test.** The Mann-Whitney U test and Kruskal-Wallis test were conducted to answer Question 1. The Kruskal-Wallis test is the non-parametric alternative to a one-way between-groups ANOVA, and is used for independent variables with three or more groups (Pallant, 2013). For example, it was used to determine the relationship between age (three categories: 30-54 years, 55-74 years, >75 years) and D2ECG time, as well as chief complaint (three categories) and D2ECG time. Similarly, the Mann-Whitney U test is the non-parametric alternative to the t-test, used when the two samples are not normally distributed but are derived from the same population exhibiting the same shape (LaMorte, 2017). The distributional properties of the two groups were determined by inspection and examining measures of skewness and kurtosis to determine if median or mean ranks would be used for analysis (Polit & Beck, 2012). If the time data were similarly distributed in the two groups, then the medians would be used to compare the difference in D2ECG times (Polit & Beck, 2012). However, if the time data were differently distributed, then the Mann-Whitney U test would be used to compare means ranks (Polit & Beck, 2012). Accordingly, the Mann-Whitney U test was used to test the differences between the two independent groups’ D2ECG times (Questions 2 and 3).

**Regression Analysis.** We employed hierarchical multiple linear regression to answer Question 4, allowing us to adjust for relevant clinical and demographic variables (e.g., age, sex, chief complaint, and arrival time) that may be associated with patients’ D2ECG times. This type of regression allowed each candidate predictor to be entered in a series of steps in which the order of entry was determined based on theory and clinical judgment (Polit & Beck, 2012). We evaluated the contribution of the predictor variables to D2ECG time in the final model. Before conducting the multiple regression analysis, we examined the data to ensure that several
assumptions were satisfied: sample size (as described earlier), multicollinearity, outliers, normality, linearity, and homoscedasticity (Pallant, 2013). Multicollinearity is the relationship between the independent variables, and it exists if $r=0.9$ or greater (Pallant, 2013). Multiple regression is very sensitive to outliers, therefore extreme scores need to be evaluated and potentially removed from the complete dataset, standardized residual plots can be used to determine outliers on the dependent variable, with parameters for outliers outside the -3.3 to 3.3 residual value (Pallant, 2013).

Normality, linearity and homoscedasticity refer to the distribution of scores and the relationship between the variables. After examination of the data, log-transformation of the D2ECG variable was undertaken, to meet all assumptions of the multiple regression. For all statistical tests, $p = 0.05$ was considered significant.
Chapter 4: Results

This chapter provides a description of the study sample and a comparison of the demographics between the pre- and post-implementation groups among the suspected ACS and cardiac arrhythmia samples. The remainder of the chapter will present the findings from inferential statistical procedures that were carried out to answer the four research questions. The results are based on a combination of statistical analyses which include Mann-Whitney U test, Kruskal-Wallis Test and linear regression models.

Study Sample

During the two 9-month study periods, January 01, 2016 to September 30, 2016 (group 1) and January 01, 2017 to September 30, 2017 (group 2), a total of 4920 patient cases were included, based on the study inclusion criteria. To address outliers, 805 of the total 4920 cases (16%) were not included in the analysis due to missing ECG data (n=40), and outliers, defined by D2ECG times greater than 180 minutes (n=765). The proportion of cases removed from each of the phases was similar (17% pre-implementation; 16% post-implementation). The rationale for removing the outliers was decided by examining the frequency distribution and the interquartile range (IQR) of D2ECG times in the dataset. For example, 417 cases (55% of the outliers) had a D2ECG time, which ranged from 6 hours to 53 days. Extreme outliers can be determined to be three times the third quartile range, and for our dataset was calculated to be 237 minutes (Polit & Beck, 2012). We further reduced the calculated extreme outlier limit by 57 minutes. We argue that D2ECG times exceeding 180 minutes would be clinically irrelevant to our research questions; values greater than this would be suggestive of an error in data entry for either the arrival time or the ECG acquisition time.
After accounting for the missing ECG data and outliers, 4115 cases were used for analysis (2637 [64%] suspected ACS, 1478 [36%] suspected cardiac arrhythmia), represented in Table 3. There were 2042 patients in the pre-implementation group, 1307 (64%) of which were triaged as suspected ACS and 735 (36%) were triaged as cardiac arrhythmia. In the post-implementation group, there were 2073 patients, of which 1330 (64%) were suspected ACS and 743 (36%) were triaged as cardiac arrhythmia.

Table 3.

<table>
<thead>
<tr>
<th>Patient Groups, by Implementation Phase</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pre-Implementation Phase (Group 1)</td>
</tr>
<tr>
<td>(January 1, 2016 to September 30, 2016)</td>
</tr>
<tr>
<td>1307 Suspected ACS</td>
</tr>
<tr>
<td>735 Suspected Cardiac Arrhythmia</td>
</tr>
<tr>
<td>2042 Total Sample</td>
</tr>
<tr>
<td>----------------------------------------</td>
</tr>
<tr>
<td>Post-Implementation Phase (Group 2)</td>
</tr>
<tr>
<td>(January 1, 2017 to September 30, 2017)</td>
</tr>
<tr>
<td>1330 Suspected ACS</td>
</tr>
<tr>
<td>743 Suspected Cardiac Arrhythmia</td>
</tr>
<tr>
<td>2073 Total Sample</td>
</tr>
<tr>
<td>----------------------------------------</td>
</tr>
<tr>
<td>Total Sample</td>
</tr>
<tr>
<td>2637 Suspected ACS</td>
</tr>
<tr>
<td>1478 Suspected Cardiac Arrhythmia</td>
</tr>
<tr>
<td>4115 Total Sample</td>
</tr>
</tbody>
</table>

Preliminary Analysis

Baseline demographic and clinical characteristics of the suspected ACS and cardiac arrhythmia groups are presented in Table 4a and 4b, respectively. In the suspected ACS group, there were no statistically significant differences in age or sex between implementation phases (pre-and post). The average age for the pre-implementation group was 60.99 years (SD=14.6) and for post-implementation phase 61.39 years (SD=14.7), p=0.488. Clinical factors such as chief complaint and arrival time were found to be statistically significantly different between the pre- and post-implementation groups; however, the absolute differences in frequencies were small and therefore likely not clinically important. The majority of suspected ACS patients in
each phase presented during the daytime and “chest pain, cardiac features” was the predominant presenting chief complaint.

In the suspected cardiac arrhythmia group, there was no statistically significant difference in age, sex, triaged chief complaint or time of arrival, as shown in Table 4b. The majority of suspected cardiac arrhythmia patients presented during the day time and “dysrhythmia/palpitations, with normal vitals” was the most common presenting chief complaint in both the pre- and post-implementation phases for this group. The average age for the pre-implementation group was 60.53 years (SD=15.6) and for post-implementation phase 60.84 years (SD=16.2), p=0.707. Figure 1 illustrates the median D2ECG times for the two 9-months phases among suspected ACS patients.

Table 4a. Baseline Characteristics of Suspected ACS Patients, by Implementation Phase

<table>
<thead>
<tr>
<th>Characteristic</th>
<th>Pre-implementation</th>
<th>Post-implementation</th>
<th>p-value</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>(n=1307)</td>
<td>(n=1330)</td>
<td></td>
</tr>
<tr>
<td>Age, years, M(SD)</td>
<td>61 (15)</td>
<td>61 (15)</td>
<td>0.488</td>
</tr>
<tr>
<td>Sex, n (%)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Male</td>
<td>690 (53)</td>
<td>709 (53)</td>
<td>0.791</td>
</tr>
<tr>
<td>Female</td>
<td>617 (47)</td>
<td>621 (47)</td>
<td></td>
</tr>
<tr>
<td>Chief Complaint, n (%)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Chest Pain, cardiac features</td>
<td>1004 (77)</td>
<td>985 (74)</td>
<td></td>
</tr>
<tr>
<td>Chest Pain, resolved, significant cardiac history</td>
<td>196 (15)</td>
<td>257 (19)</td>
<td>0.007</td>
</tr>
<tr>
<td>Chest Pain + moderate to severe symptoms</td>
<td>107 (8)</td>
<td>88 (7)</td>
<td></td>
</tr>
<tr>
<td>Time of arrival, n (%)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Day (0800-1959)</td>
<td>872 (67)</td>
<td>949 (71)</td>
<td>0.010</td>
</tr>
<tr>
<td>Night (2000-0759)</td>
<td>435 (33)</td>
<td>381 (29)</td>
<td></td>
</tr>
</tbody>
</table>

a Student t test.

b Chi-square test.
Table 4b.

**Baseline Characteristics of Suspected Cardiac Arrhythmia Patients, by Implementation Phase**

<table>
<thead>
<tr>
<th>Characteristic</th>
<th>Pre-implementation (n=735)</th>
<th>Post-implementation (n=743)</th>
<th>p-value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Age, years, M(SD)</td>
<td>61 (16.0)</td>
<td>61 (16.0)</td>
<td>0.707&lt;sup&gt;a&lt;/sup&gt;</td>
</tr>
<tr>
<td>Sex, n (%)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Male</td>
<td>359 (49.0)</td>
<td>328 (44.0)</td>
<td>0.070&lt;sup&gt;b&lt;/sup&gt;</td>
</tr>
<tr>
<td>Female</td>
<td>376 (51.0)</td>
<td>415 (56.0)</td>
<td></td>
</tr>
<tr>
<td>Chief Complaint</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Dysrhythmia/palpitations, normal vitals</td>
<td>366 (50.0)</td>
<td>363 (49.0)</td>
<td></td>
</tr>
<tr>
<td>Dysrhythmia/palpitations, abnormal vitals</td>
<td>312 (42.0)</td>
<td>298 (40.0)</td>
<td></td>
</tr>
<tr>
<td>Palpitations, resolved</td>
<td>52 (7.0)</td>
<td>67 (9.0)</td>
<td>0.117&lt;sup&gt;b&lt;/sup&gt;</td>
</tr>
<tr>
<td>Palpitations, firing of internal defibrillator</td>
<td>3 (0.5)</td>
<td>7 (1.0)</td>
<td></td>
</tr>
<tr>
<td>Dysrhythmia/palpitations, severe hypotension or shock</td>
<td>2 (0.5)</td>
<td>8 (1.0)</td>
<td></td>
</tr>
<tr>
<td>Time of arrival, n (%)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Day (0800-1959)</td>
<td>515 (65.0)</td>
<td>515 (65.0)</td>
<td>1.000&lt;sup&gt;b&lt;/sup&gt;</td>
</tr>
<tr>
<td>Night (2000-0759)</td>
<td>279 (35.0)</td>
<td>279 (35.0)</td>
<td></td>
</tr>
</tbody>
</table>

<sup>a</sup> Student t test.
<sup>b</sup> Chi-square test.
Figure 1.

**Median D2ECG Time in Minutes by Implementation Phase Among Suspected ACS patients**

The distribution of scores for D2ECG times in minutes was skewed to the right (Figure 2) and would therefore violate the assumption of normality for the parametric statistics, such as the t-test and one-way ANOVA (Pallant, 2013). Therefore, the non-parametric alternative to these statistics, the Mann-Whitney U test and Kruskal-Wallis test, respectively, were used for our analysis of D2ECG times (Pallant, 2013).
Research Question 1: Factors Associated with D2ECG Times

All suspected ACS patients (n=2637) were included in this analysis. Analysis revealed that only age and sex were significantly associated with D2ECG times (see Table 5). A Mann-Whitney U test revealed shorter D2ECG times for men (Mdn= 24 minutes, IQR, 9-47) compared with women (Mdn =28 minutes, IQR, 11-49), U =817918; z= -2.464), p= 0.014, r= 0.05. Using the Cohen (1988) criteria for small effect size of 0.1, our effect size was determined to be very small, concluding that sex has a small effect on D2ECG times. A Kruskal-Wallis test revealed a statistically significant difference in D2ECG across three different age groups (Gp1: 30-54 years, Gp2: 55-74 years, Gp3: 75-99 years), Kruskal-Wallis H (2, n=2637) = 11.540, p=0.003. The median D2ECG times for each age category revealed that Group 3, the oldest group, had longer
D2ECG times ($Mdn=29$ minutes, $IQR$, 12-51) than Group 1 ($Mdn=26$ minutes, $IQR$, 10-47) and Group 2 ($Mdn=23$ minutes, $IQR$, 10-45). A post-hoc analysis using a Mann-Whitney U test was used to identify which group(s) was statistically significantly different (Pallat, 2013). This was done by comparing each group with one another (Gp1 with Gp2, Gp1 with Gp3, and Gp2 with Gp3), and the following $p$-values were calculated 0.30, 0.02, and 0.00 respectively. Next, to control for a Type I error, a Bonferroni correction of ($\alpha_{altered}=.05/3$) =0.017 was applied to these $p$-values. The Bonferroni correction revealed that was there was a statistically significant difference only between Gp2 and Gp3, but not between Gp1 and Gp2, or between Gp1 and Gp3. This indicates that individuals older than 75 years had a statistically significantly longer D2ECG times when compared to patients aged 55-74 years. Conversely, arrival time and chief complaint codes were not statistically associated with D2ECG time, as tested by a Mann-Whitney U test.
Table 5.

**D2ECG Time, Among Suspected ACS Patients, by Selected Clinical and Demographic Variables**

<table>
<thead>
<tr>
<th>Characteristic</th>
<th>n (N = 2637)</th>
<th>D2ECG time, minutes</th>
<th>p-value</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Age</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>30-54 years</td>
<td>885</td>
<td>26 (10-47)</td>
<td>0.003&lt;sup&gt;b&lt;/sup&gt;</td>
</tr>
<tr>
<td>55-74 years</td>
<td>1233</td>
<td>23 (10-45)</td>
<td></td>
</tr>
<tr>
<td>&gt;75 years</td>
<td>519</td>
<td>29 (12-51)</td>
<td></td>
</tr>
<tr>
<td><strong>Sex</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Male</td>
<td>1399</td>
<td>24 (9-47)</td>
<td>0.014&lt;sup&gt;a&lt;/sup&gt;</td>
</tr>
<tr>
<td>Female</td>
<td>1238</td>
<td>28 (11-49)</td>
<td></td>
</tr>
<tr>
<td><strong>Chief Complaint</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Chest Pain, cardiac features</td>
<td>1989</td>
<td>25 (10-46)</td>
<td>0.280&lt;sup&gt;b&lt;/sup&gt;</td>
</tr>
<tr>
<td>Chest Pain, resolved, significant cardiac history</td>
<td>453</td>
<td>30 (9-55)</td>
<td></td>
</tr>
<tr>
<td>Chest Pain + moderate to severe symptoms</td>
<td>195</td>
<td>24 (12-46)</td>
<td></td>
</tr>
<tr>
<td><strong>Time of arrival</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Day (0800-1959)</td>
<td>1821</td>
<td>26 (10-47)</td>
<td>0.252&lt;sup&gt;a&lt;/sup&gt;</td>
</tr>
<tr>
<td>Night (2000-0759)</td>
<td>816</td>
<td>26 (11-47)</td>
<td></td>
</tr>
</tbody>
</table>

*Note. D2ECG, door-to-ECG; ACS, acute coronary syndrome; Mdn, median; IQR, interquartile range*

<sup>a</sup> Mann-Whitney U test  
<sup>b</sup> Kruskall Wallis test

**Research Question 2: Effects of Implementation of Pre-Registration ECGs on D2ECG Times Among Patients with Suspected ACS**

Table 6 shows that D2ECG times were shorter for suspected ACS patients in the post-implementation phase (*Mdn*=10 minutes, *IQR*, 7-21, *n*=1307) than those in the pre-implementation phase (*Mdn*= 40 minutes, *IQR*, 28-59, *n*=1330). *U*=264939, \( z = -30.917, p = 0.000, r = 0.58 \). Using the Cohen (1988) criteria for a large effect size of 0.5, the effect size was determined to be large, suggesting that the new triage process had a large effect on D2ECG times.
by decreasing D2ECG time among patients with suspected ACS. We also found that 1.3% \((n = 17)\) of suspected ACS patients received an ECG within 10 minutes in the pre-implementation phase compared to 51% \((n = 671)\) in the post-implementation phase (see Table 6).

Table 6.

<table>
<thead>
<tr>
<th>Characteristic</th>
<th>Pre-intervention ((n=1307))</th>
<th>Post-intervention ((n=1330))</th>
<th>(p)-value (^a)</th>
</tr>
</thead>
<tbody>
<tr>
<td>D2ECG time, minutes, (Mdn (IQR))</td>
<td>40 (28-59)</td>
<td>10 (7-21)</td>
<td>0.00</td>
</tr>
<tr>
<td>ECG within 10 minutes or less, (n(%))</td>
<td>17 (1.3)</td>
<td>671 (50.5)</td>
<td>0.00</td>
</tr>
</tbody>
</table>

*Note. D2ECG, door-to-ECG; ACS, acute coronary syndrome; \(Mdn\), Median; IQR, interquartile range

\(^a\) Mann-Whitney U test

**Research Questions 3: Effects of Implementation of Pre-Registration ECGs on D2ECG Among Patients with Suspected Cardiac Arrhythmia**

Table 7 shows the association of implementation phase with D2ECG times among suspected cardiac arrhythmia patients, which was also statistically significantly shorter in the post-implementation phase \((Mdn=24\) minutes, IQR, 10-50, \(n=735)\) than those in pre-implementation phase \((Mdn= 45\) minutes, IQR, 29-67, \(n=743)\), \(U=166329, z=-13.010, p= 0.000, r= 0.34\). Using the Cohen (1988) criteria for medium effect size of 0.3, the effect size was determined to be medium; that is, the new triage process had a medium effect on D2ECG times, by decreasing D2ECG time among patients with suspected cardiac arrhythmias.
Table 7.

D2ECG Among Cardiac Arrhythmia Patients, by Implementation Phase

<table>
<thead>
<tr>
<th>Characteristic</th>
<th>Pre-implementation (n=735)</th>
<th>Post-implementation (n=743)</th>
<th>p-value ( ^a )</th>
</tr>
</thead>
<tbody>
<tr>
<td>D2ECG time, minutes, ( Mdn \ (IQR) )</td>
<td>45 (29-67)</td>
<td>24 (10-50)</td>
<td>0.00</td>
</tr>
</tbody>
</table>

*Note,* D2ECG, door-to-ECG; \( Mdn \), median; \( IQR \), interquartile range

*\(^a\) Mann-Whitney U test*

**Research Question 4: Effect of Implementation of Pre-registration ECGs (Adjusted) on D2ECG time Among Suspected ACS Patients**

**Variable Transformation.** As the distribution of scores for D2ECG times in minutes was skewed to the right (see Figure 2) and would, therefore, violate the multiple regression assumption of normality (Pallant, 2013), a new variable was created: logarithm of D2ECG time in minutes. The effect of the transformation is illustrated in Figure 3.

Figure 3.

*Histogram of Frequency Distribution of the log (D2ECG time), Suspected ACS Patients*
Hierarchical Multiple Regression. Hierarchical multiple regression was used to assess the effect of pre-registration ECGs on D2ECG times, after controlling for the influence of age and sex. Preliminary analyses were conducted to ensure there were no violations of the assumptions of multicollinearity, normality, linearity, and homoscedasticity (Pallant, 2013). The collinearity diagnostics, tolerance and variance inflation factor (VIF), were used to check for multicollinearity. Tolerance values less than 0.10 and VIF (inverse of tolerance) values greater than 10 would be of concern, indicating multicollinearity; based on our diagnostics (illustrated by Table 8), the data did not violate this assumption. These diagnostics confirmed that age, sex, and phase were not intercorrelated at the bivariate level and therefore could be examined separately to evaluate their unique effects on D2ECG time. The Normal P-P plot (see Figure 4) showed no significant deviations from normality by demonstrating a reasonably straight diagonal line. Finally, Figure 5 illustrates that the residuals are distributed throughout the plot with no specific pattern suggesting that our regression model did not violate the assumption of homoscedasticity.

$R^2$, $R^2$ change and beta coefficients were examined to determine the relationship between variables and their contribution to the overall model. Age and sex were entered at step 1, yielding an $R^2$ of 0.004, $p=0.01$, which meant that only 0.4% of the variance in log (D2ECG time) was explained by these two variables. After entry of the implementation phase variable at step 2, the $R^2=0.36$, and therefore the total variance explained by the model as a whole was 36%, $F (3, 2631) =491.00$, $p=0.00$. These findings suggest that the new triage process explained almost all of the 36% of the variance in log (D2ECG times), after controlling for age and sex: $R^2$ change = 0.36, $F$ change (1, 2631) =1456.50, $p=0.00$. In the final model, age, sex, and phase were statistically significant, with implementation phase demonstrating the highest beta value ($beta= -$
0.60, \( p=0.00 \), as shown in Table 8. In multiple regression, the estimated effect size is a function of the \( R^2 \); the conventional value for a large effect size is indicated by \( R^2=0.30 \) (Polit & Beck, 2012). In our final regression model, \( R^2=0.36 \), which indicates a large effect size and suggests that the new triage process had a large effect on D2ECG time among suspected ACS patients.

In our model, the dependent variable (D2ECG time) was log-transformed and the independent variables remained unchanged. Therefore, to allow meaningful interpretation of the effects of each predictor variable (age, sex, phase), we exponentiate the beta coefficients and converted the results into percentages. This calculation explained the percentage of change in D2ECG time by each predictor variable. Thus, patients’ D2ECG time was decreased by 81% when the new triage process was applied. D2ECG time was increased by 5% for each year of age, and increased by 4% if the patient was female.

Table 8.

**Coefficient Table for the Final Regression Model**

<table>
<thead>
<tr>
<th>Characteristic</th>
<th>Unstandardized coefficients</th>
<th>Standardized coefficients</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Beta</td>
<td>Std. Error</td>
</tr>
<tr>
<td>Age, years</td>
<td>0.01</td>
<td>0.00</td>
</tr>
<tr>
<td>Sex, male/female</td>
<td>0.04</td>
<td>0.01</td>
</tr>
<tr>
<td>Phase, pre-intervention/post-intervention</td>
<td>-0.49</td>
<td>0.01</td>
</tr>
</tbody>
</table>

*Note.* Dependent variable is log (D2ECG time) measured in minutes
Figure 4.

Probability Plot (P-P) of the Regression Standardized Residual, Dependent Variable: log (D2ECG time) in Minutes

Figure 5.

Scatterplot of the Standardized Residuals, Dependent Variable: log (D2ECG time) in Minutes
Chapter Summary

The findings presented above indicate that the use of pre-registered ECGs is a strong predictor of reduced D2ECG time, after controlling for age and sex. Men with suspected ACS received an ECG four minutes faster than women, irrespective of implementation phase. Similarly, suspected ACS patients aged 55-74 years received an ECG three to six minutes faster than patients outside of this age range. Chief complaint codes entered at triage and time of arrival did not affect D2ECG times. Prior to the implementation of the pre-registered ECGs, the median D2ECG time was determined to be 40 minutes, whereas after implementation, the median D2ECG time decreased to 10 minutes. The use of pre-registered ECGs had no detrimental effect on D2ECG time among suspected cardiac arrhythmia patients; in fact, it was also associated with a statistically significant shorter D2ECG time among these patients.
Chapter 5: Discussion

The purpose of this retrospective study was to investigate the effect of pre-registration ECGs for walk-in patients with suspected ACS, on D2ECG time. A 12-lead ECG is the primary step for initiating the treatment pathway to restore coronary blood flow among STEMI patients (Krumholz, et al., 2008). A delay in this process is associated with greater damage to the heart muscle and mortality and therefore, rapid ECG acquisition is a crucial initial step in achieving timely coronary reperfusion (Krumholz, et al., 2008; & Diercks et al., 2006). As a result, the American College of Cardiology and the American Heart Association (ACC/AHA) recommends that D2ECG acquisition time should be 10 minutes or less (Krumholz, et al., 2006). This chapter will provide a summary of key findings and their implications for future research and practice. In the first section of this chapter, our study’s key findings are reviewed. In the second section, strengths and limitations are examined. Lastly, implications for research and clinical practice will be discussed.

Synthesis of Key Findings

Factors Associated with D2ECG Times Among Suspected ACS Patients. Of the clinical and demographic variables available to us, only sex and age were associated with D2ECG times for walk-in patients with suspected ACS (including patients in both phases). Women and older patients received delayed ECGs, whereas time of arrival and chief complaint did not predict D2ECG times. Delays in D2ECG times among older patients may be related to their physical limitations such as reduced mobility and the atypical presentation of their symptoms (Engberding & Wenger, 2017). Our findings regarding sex differences are consistent with several reports (Diercks et al., 2006; Glickman et al., 2010; Pelletier et al., 2014; & Mackay et al., 2018), though some studies (Pearlman et al., 2008; Yates et al., 2011; & Spence et al.,
have not found these factors to be significant. After controlling for other predictors, our findings provide evidence that women do have longer D2ECG times than men (Pearlman et al., 2008; Miro et al., 2009). This may be attributed to the fact that women are more likely to present with atypical symptoms of chest pain, or that care providers may treat men and women systematically differently and consequently delay their ECG acquisition (Graham, 2016). A further explanation was suggested by Pelletier and colleagues (2014), who took a unique approach to exploring this issue. Interestingly, they found that feminine personality traits were associated with delayed D2ECG times and overall access to care.

Our findings indicated that arrival time and chief complaint were not associated with D2ECG times. Similarly, Dasari and colleagues (2014) found no association between arrival time and D2ECG times. However, Atzema et al., 2009; Atzema et al., 2011; & Nonnenmacher et al., 2018 found that chief complaint codes and low priority triage scores were predictors of D2ECG times. These conflicting findings may be caused by the various triaging systems that exist; for example, Nonnenmacher and colleagues (2018) conducted their study in Brazil where the Manchester Triage System (MTS) is used and the authors reported 87% sensitivity rate for triaging chest pain patients. This information provides an opportunity for future investigations to explore accuracy of triage coding.

**Effect of New Triage Process on D2ECG Time.** There was a statistically significant decrease in D2ECG times among walk-in patients with suspected ACS following the implementation of the new triage process. D2ECG time within 10 minutes is an important indicator for quality of care delivery among ACS patients and our results showed that 51% of suspected ACS patients received an ECG within 10 minutes after the implementation of pre-registered ECGs. These results are slightly higher than the study conducted by Diercks and
colleagues (2006) where eight hospitals in North America achieved D2ECG benchmarks for 33% of ACS patients overall. Previous studies conducted by Sprockel et al. (2015) and Takauwa et al. (2009) that used a similar multifaceted strategy for improving D2ECG time found slightly higher performance in achieving D2ECG time within 10 minutes: 64% and 63%, respectively. This suggests that while the pre-registered ECG in our study was effective in improving D2ECG times, additional supports may be required to further improve/boost/augment the performance to achieve best-practice guidelines.

Our finding was consistent with several intervention studies that also implemented new strategies to improve D2ECG times. Similar to our intervention, these studies used a multifaceted, multidisciplinary strategy for implementing a new triage process. The intervention implemented by Takakuwa and colleagues (2009) involved educating the staff and activating a call to alert the ECG technician to deliver the ECG to the ED service physician who registered the ECG time. Phelan and colleagues’ (2009) intervention involved i) implementing a patient prioritization triage process, ii) providing staff education, iii) assigning registration as a nurse duty, and iv) providing continuous surveillance on D2ECG time. Coyne and colleagues (2015), assigned an intake nurse to respond to all urgent and emergent cardiac-based chief complaints. This nurse then obtained an immediate ECG, and delivered it to the ED physician for interpretation and possibly STEMI activation. Although the interventions vary, they implied a similar systematic process which included staff education, modification of the registration process and role restructuring within the ED.

Suspected cardiac arrhythmia patients also benefited from the implementation of the new triage process. We explore the potential for delays in ECG acquisition in patients who were not targeted by the intervention. However, we did not find any evidence of unintended delayed
D2ECG time among patients with suspected cardiac arrhythmia who were not targeted by the intervention. In fact, improvements in D2ECG times were also observed. Overall, our findings suggest that the new triage process is an effective method for reducing D2ECG times among suspected ACS patients, with no identified additional resources such as staffing levels, including ECG technicians.

**Adjusted effect of implementation of pre-registration ECGs.** The regression analysis indicated that age, sex, and the new triage process all uniquely contributed to D2ECG times. The implementation of the new triage process however, was the strongest predictor to D2ECG time, again showing the effectiveness of this intervention.

The success of the implementation of the new triage process may be attributed a few factors that were not tested in our study. One was the quality improvement team’s commitment to developing and implementing a standardized process and supporting staff (personal communication, L. Korchinski, Manager, Emergency Department). A second factor was using an interdisciplinary approach to educate the triage nurses, ED physicians and ECG technicians on the management of ACS. Finally, creating a dedicated ECG space played a pivotal role in the project’s success (personal communication, L. Korchinski, Manager, Emergency Department).

**Strengths and Limitations**

This study had three main strengths. First, the large sample size increased the power of our study and reduces the chance of a Type II error, thus providing reliable results and greater precision (Polit & Beck, 2012). Second, our study was conducted over two 9-month study periods, January 01, 2016 and September 30, 2016 (group 1) and January 01, 2017 and September 30, 2017 (group 2), allowing us to evaluate whether improvements were sustained.
Third, our study examined possible untoward effects by analyzing D2ECG times on another related patient population, suspected cardiac arrhythmia patients. None of the studies identified on the literature review examined unintended effects in other patient populations. We were able to consider the effects of the implementation of the new process simultaneously on both patient populations, suspected ACS and suspected cardiac arrhythmia patients.

Despite the strengths of our study, there are important limitations. A primary limitation was our study design, which was a retrospective, quasi-experimental design using a historical comparison group. While other intervention studies on this topic have used a similar design, (Purim-Shem-Tov et al., 2007; Phelan et al., 2009; Takakuwa et al., 2009; Ballard et al., 2011; Sprockel et al., 2015; Coyne et al., 2015; Keats et al., 2018; & Stanfield, 2018), this type of design is limited by the lack of randomization and control over possible confounders as well as the influence of possible co-interventions. Given that our intervention was a multifaceted approach, we were unable to evaluate which specific aspects of the intervention led to the improvement of D2ECG times. For example, we were unable to establish whether a Hawthorne effect, education, educational material or the designated ECG space made the difference in D2ECG time.

Another limitation was that we did not study clinical outcomes, as it was not the primary focus of the study. Therefore, we were unable to determine which patients were diagnosed with a STEMI, their associated treatment times, or the incidence of mortality. Therefore, we cannot conclude the improvements on D2ECG times found in our study were associated with improved patient outcomes. However, it is acknowledged in the literature that improving D2ECG times improves coronary reperfusion time and patient outcomes (Atzema et al., 2011 & Coyne et al., 2015).
Our study was conducted at a single, large urban site and therefore the study findings have limited generalizability. Also, our study focused on those triaged as “chest pain”, so our findings are not generalizable to non-chest-pain symptom presentations. Several investigators have found that non-chest-pain presentations of ACS result in delayed ECG acquisition (Diercks et al., 2006; Pelletier et al., 2014; & Na et al., 2014), but it is unknown whether there were improvements in this group following implementation of the new process.

Another limitation to our study is that it was not designed to collect data on other patient, nurse and organizational factors that may have influenced D2ECG time. For example, our study did not examine patient factors such as ethnicity/racial identity or comorbidities which may be associated (either negatively or positively) with accurate identification of ACS and timely ECG acquisition. We did not explore triage nurses’ judgment or level of experience, as it would have required detailed qualitative data collection, which was beyond the scope of our study. However, considerable evidence indicates that nurses’ judgment has a significant effect on early identification of suspected ACS patients and acquisition of 12-lead ECGs (Arslanian-Engoren, 2009). Consequently, how much this variation influenced nurses’ decisions to order ECGs in the pre- or post-implementation group in this study is not known. Organizational factors such as ED overcrowding and staffing levels were not investigated in our study. A systematic review conducted by Morley and colleagues (2018) indicated that ED overcrowding leads to poor patient outcomes and limited adherence to best practice guidelines by staff. However, the study conducted by Mazurek and colleagues (2017) did not identify any relationship between the rates of adherence with STEMI best-practice benchmarks, which included D2ECG time and the volume of STEMI patients across three hospital sites. Although our study was conducted over
two 9-month periods, this may not have been sufficient to control for ED trends and variable ED volumes.

**Implications**

The findings from our study have offered some important insight for future research and practice.

**Future Research.** First, exploration of patients’ ethnicity or racial identity, socioeconomic status and comorbidities, should be considered for future research as they may shed light on important factors affecting D2ECG time. Findings have been inconsistent regarding an association between ethnicity/race and D2ECG times (Pearlman et al., 2008; Yates et al., 2011; & Mackay et al., 2018). However, some studies were conducted in the United States, so to better understand if race or ethnicity play a role in ECG acquisition among Canadian patients, further research is required. Comorbidities, including depression, diabetes mellitus, hypertension and family history of coronary artery disease (CAD) have been briefly explored in the literature, showing an association with delayed ECG acquisitions (Atzema et al. 2011 & Pelletier et al., 2014) and warrant further study to better understand this link. Also, future interventional studies should consider making statistical adjustments to predictor variables: age, arrival time, and chief complaint.

Second, to date, ED overcrowding and its effects on D2ECG times has not been directly investigated and may be important to examine if high patient volumes are associated with the accuracy of triage nurses’ decision making when triaging suspected ACS patients. Mazurek et al., (2017) did not identify any relationship between the rates of adherence with STEMI benchmarks and the volume of STEMI patients across three hospitals. As well, it may be important to explore to if there is an association between ED overcrowding and ECG
technicians’ availability when prioritizing this potentially high-risk population, irrespective of triage processes. Data on ED patient volumes, seasonal trends, staff levels and workload would need to be collected to conduct a detailed analysis of these possible predictors.

Third, information on years of experience, level of education and level of specialty training, may be important to collect to explore their effect on triage nurses’ decision-making in assigning priority to suspected ACS patients irrespective of the triage process.

**Clinical Practice.** Our results provide some insight for improving clinical practice. While our study did not examine factors related to triage nurses’ decision-making, it seems likely that the supportive education provided to the staff contributed to improvement in identifying potential ACS patients and therefore reducing D2ECG times. Our findings showed that older patients had longer ECG acquisition times, which has also been reported in the literature (Keats et al., 2018 & Mackay et al., 2018). Therefore, supportive educational tools for emergency nurses should be developed to improve rapid recognition of ACS among populations who may present atypically. Additionally, the implementation of this triage process was a cost-effective and efficient strategy for improving D2ECG times in the ED. Perhaps similar, multifaceted approaches, utilizing existing resources, staff education, clinical pathways and audits, would be effective for achieving best-practice guidelines in other high-risk patient populations, such as stroke and sepsis.

**Conclusion**

Overall, our findings suggest that a triage process involving obtaining pre-registered ECGs, a designated ECG space, and educational support to staff can successfully improve D2ECG times for suspected ACS patients. The standardized process for identifying suspected ACS patients and obtaining timely ECGs was implemented successfully without modifying staff resources or adding technical support. Further research is required to investigate other
extraneous factors which may influence D2ECG time, such as patient, nursing and organizational factors. As well, education for nursing staff about women’s and older patients’ presentations are recommended.
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Wilkins.


