Stephen Aiello

Comparison of Ambulance Officer Working Diagnosis of ST-Elevation Myocardial Infarction with Final Hospital Diagnosis: An Observational Study

2020

Department of Paramedicine, School of Clinical Sciences,

Faculty of Health and Environmental Science

A thesis submitted to Auckland University of Technology in fulfilment of the requirements of the degree of Master of Philosophy (MPhil)

Abstract

Cardiac disease is a leading cause of morbidity and mortality around the world, accounting for more than one-third of total deaths. Cardiac disease causes myocardial infarction and affects thousands of New Zealanders each year. An ST-Elevation Myocardial Infarction (STEMI) is a myocardial infarction identifiable by an elevated ST-segment on the electrocardiograph. STEMI is thought to represent approximately 33% of myocardial infarction presentations and is associated with delayed diagnosis and an increased risk of death. There is evidence that ambulance officers can recognise STEMI from a 12-lead ECG, however, the accuracy of STEMI diagnosis varies between studies and there is no direct comparison to the New Zealand context.

The primary aim of this thesis was to investigate whether those patients with STEMI were recognised as having STEMI by ambulance officers when compared with confirmed hospital diagnosis of STEMI. The secondary aim was to identify predictors of ambulance and hospital diagnostic agreement.

This cross-sectional study linked data from the Auckland ambulance service electronic patient report forms, with patient data from hospital medical records, to explore diagnostic agreement. The observational study adopted a quantitative approach and included records for 268 cases.

This study found that the sensitivity of ambulance officer STEMI diagnosis was 84.3% and the specificity was 53.5%. The high sensitivity indicated that the ambulance officer will rarely miss a STEMI for those patients who had the condition. The low specificity implied a potential to overestimate STEMI with a high number of false-positives. However, a low specificity may be acceptable when the patient is suspected of having a time-critical life-threatening medical emergency such as STEMI. The downside to this is the potential complications to the wider system of care such as incorrect early activation and/or bypass toward the cardiac catheterisation laboratory or the inappropriate administration of thrombolytic therapy.

Results from the secondary outcomes indicated the strongest predictors for diagnostic agreement were the ambulance retrieval location type and patient symptom severity. When compared to the retrieval of a patient from the home location, a patient referred from a healthcare facility was three times less likely to have diagnostic agreement with the hospital. Finally, patients assessed with initial clinical symptom severity of Status

Two, when compared to those assessed at Status One (more severe), were less likely to have diagnostic agreement with the hospital.

This study highlights several important aspects regarding the current prehospital system of care within New Zealand. The diagnosis of STEMI by ambulance officers within the prehospital environment is possible, but there remains a high level of incorrect diagnosis to support a truly autonomous model of ambulance officer initiated hospital bypass or thrombolysis. This research provides an understanding of current clinical practice and can help to inform policy, education and most importantly, clinical practice.

Keywords: Ambulance officer; Paramedic; ST-elevation myocardial infarction; STEMI; Diagnostic accuracy; Prehospital; New Zealand.

Table of contents

List of Figures

List of Tables

Attestation of Authorship

I hereby declare that this submission is my own work and that, to the best of my knowledge and belief, it contains no material previously published or written by another person (except where explicitly defined in the acknowledgements), nor material which, to a substantial extent has been submitted for the award of any degree or diploma of a university or other institution of higher learning.

Stephen Aiello, 21st January 2020.

Acknowledgements

This thesis represents the culmination of a significant journey; the path of which would have been difficult to navigate without the significant contribution, support, and encouragement of many others. I take this opportunity to personally offer my heartfelt thank you to all those that have facilitated my road to submission of this thesis. When I reflect I am conscious of the significant number of people that have encouraged, offered guidance and critique; there are too many people to name all, but I would like to specifically acknowledge the expert guidance, support and encouragement provided by my supervisors, Dr Bronwyn Tunnage and Adjunct Professor Bridget Dicker. In addition, I thank the following for their contribution and guidance:

Mr Tony Ward and Associate Professor Peter Larmer for their leadership and support.

The Paramedicine Team for their support, protection of my writing time and ongoing encouragement.

Dr Graham Howie for his time and expert critique of my research proposal.

St John Ambulance service for their generosity, participation, and access to data.

Northern Regional Alliance for collaborative access to data.

Mr Paul Davey for his support, guidance, and contribution.

Mr Norm Wilkinson for his encouragement and guidance.

Finally, and most importantly, I would like to acknowledge my family, Martina, and Josie, without which, this journey would not have been possible.

There are no conflicts of interest or associated financial funding to disclose.

Ethical and Locality Approval

Ethical approval for this research was sought and granted by the Auckland University of Technology Ethics Committee (AUTEC). Approval granted on 14th of November 2016 by AUTEC, the reference was 16/392 (Appendix A).

Locality review and approval was also sought from St John. St John approved the study on the 1st of December 2016; reference #53 (Appendix B).

Chapter 1 INTRODUCTION

1.1 Cardiac Disease

Cardiac disease is a leading cause of death around the world with global rates of death increasing by 41% between the years 1990 and 2013 (Roth et al., 2015). As a result of cardiac disease, in 2015, around 15.9 million myocardial infarctions occurred worldwide (Hay et al., 2017).

Statistics show that within New Zealand '1 in 20' adults live with cardiac disease (Ministry of Health, 2015). One New Zealander dies every 90 minutes with 33% of all deaths thought to be associated with cardiac disease (Ministry of Health, 2018). Each year, approximately 16,000 people with cardiac disease are admitted to a New Zealand hospital with a diagnosis of myocardial infarction (Ministry of Health, 2015). The early identification and treatment of this disease could reduce mortality and offer a model of care that addresses the needs of the New Zealand population (Burgess et al., 2011).

1.2 Acute Coronary syndromes

When at its most severe level, cardiac disease presents as one of three acute coronary syndromes: angina pectoris, non-ST-elevation myocardial infarction (NSTEMI) and ST-elevation myocardial infarction (STEMI). The extent and type of syndrome presentation will dictate the potential risk to myocardium and life.

The least serious of the acute coronary syndromes is angina pectoris. Here, an imbalance between oxygen demand and supply due to atherosclerotic plaque build-up within the coronary arteries results in periods of chest pain with little or no myocardial cell damage. This is known as myocardial ischaemia. In contrast, myocardial infarction is defined as the death of myocardial cells caused by coronary artery occlusion and prolonged ischaemia (Thygesen et al., 2012). Myocardial infarction has myocardial cell necrosis and can develop after two to four hours depending on individual oxygen demand, ischaemic zone collateral circulation and intermittent or persistent coronary occlusion. With the death of myocardial cells, a diagnosis of NSTEMI or STEMI is given (Thygesen et al., 2012).

STEMI is thought to represent approximately 33% of myocardial infarction presentation (Yeh et al., 2010). The risk of death for those patients diagnosed with STEMI is

estimated to be 10% (Steg et al., 2012) and has the same underlying coronary occlusion and subsequent myocardial cell death as NSTEMI. However, with STEMI there is a unique abnormal ST-segment elevation visible on a 12-lead ECG (Thygesen et al., 2012). STEMI is defined by a series of determinants, that together help to form a diagnosis. The diagnostic criteria will be examined in detail below.

Prehospital diagnosis of STEMI is challenging for the ambulance officer. Currently, within New Zealand, ambulance officers have no ability to investigate blood pathology in suspected cases of STEMI and must rely on clinical impression and the ability to interpret the 12-lead ECG. An understanding of ambulance officer STEMI diagnoses in addition to prehospital influences may offer some insight into prehospital diagnostic accuracy.

1.3 STEMI Management Strategy

For patients with an acute STEMI, timely diagnosis and prompt intervention are key factors in ensuring optimal patient outcome (Ibanez et al., 2017). The time from onset of symptoms until definitive treatment is a key determinant of the degree of myocardial damage, cell loss (Reffelmann, Hale, Li, & Kloner, 2002), and subsequent morbidity and mortality (Li et al., 2015). The objective is restoration of coronary blood flow, with a subsequent reduction in myocardial damage and preservation of ventricular function (Verheugt, Gersh, & Armstrong, 2006). A reperfusion strategy that encourages early treatment will, therefore, enhance acute and long-term survival (Hamer et al., 2013).

Advances in pharmacological and mechanical reperfusion strategies have improved STEMI survival and morbidity significantly (Cardiac Society of Australia and New Zealand, 2013). To combat morbidity, the use of intravenous fibrinolytic agents (thrombolysis) and percutaneous coronary intervention (PCI) produce the greatest benefit when implemented early. STEMI treatment guidelines recommending door-to-needle time for thrombolysis within 30 minutes and door-to-balloon time within 90 minutes of first contact for PCI (Cardiac Society of Australia and New Zealand, 2013).

The ability to perform timely diagnosis and prompt intervention of STEMI is complex due to the many different healthcare providers within the system of care. Individual performance needs to be evaluated so that all healthcare providers are informed and can provide efficient and effective systems of care. As part of a system of care, and to

ensure timely diagnosis and prompt intervention, ambulance officers are one of the principal treatment providers for prehospital STEMI.

Ambulance officer treatment guidelines specify the transport of patients with STEMI to a hospital for immediate PCI if symptom onset is within 90 minutes of the first diagnosis being made. Outside of the Auckland region, if the time from symptom onset to first diagnosis is greater than 90 minutes, guidelines direct the ambulance officer to administer a fibrinolytic agent. The key to the appropriate administration of fibrinolytic therapy is that the STEMI diagnosis must first be clearly and accurately identified. This thesis seeks to investigate whether those patients with STEMI are recognised as having STEMI by ambulance officers compared with confirmed hospital diagnosis of STEMI. The secondary aim is to identify predictors of ambulance and hospital diagnostic agreement.

1.4 The Ambulance Officer

There is variation internationally when investigating the ambulance officer's ability to recognise STEMI. A review of international literature has identified high levels of false-positive diagnosis of STEMI and the inappropriate activation of the cardiac catheterisation laboratory by ambulance officers when compared to a cardiologist/doctor (Davis et al., 2007; Ducas et al., 2012; Mencl et al., 2013). In contrast, other authors have reported that ambulance officers regardless of practice level or experience, can be trained to accurately interpret a 12-lead ECG for STEMI (Whitbread, Leah, Bell, & Coats, 2002). Consequently, the generalisability of these findings within the New Zealand setting is uncertain.

Qualification and skill levels differ for prehospital ambulance responders. Ambulance officer 'practice level' certification within New Zealand is dictated by the employer and is based on local service requirements and education level. Comparable to other countries, there are three common levels of ambulance certification that are recognised in New Zealand. For this thesis and unless otherwise described, 'ambulance officer' will be used as a general descriptive term for the following three ambulance practice levels found within New Zealand: Emergency Medical Technician (EMT), Paramedic (PARA) and Intensive Care Paramedic (ICP): Table 1.

Table 1 *International Ambulance Practice Levels*

Basic	Intermediate	Advanced
Emergency Medical Technician (UK/NZ/USA*)	Advanced EMT (USA*)	Intensive Care Paramedic (NZ/Australia*)
Ambulance Officer (Australia)	Paramedic (UK/Australia/USA*/NZ)	Advanced Care Paramedic (UK/USA)
Primary Care Paramedic (Canada)	Advanced Care Paramedic (Canada)	Critical Care Paramedic (Canada)

Note. NZ = New Zealand, USA = United States of America, UK = United Kingdom. * Varies by state.

1.5 System of Care

International guidelines advise PCI as the preferred reperfusion management for STEMI (Ibanez et al., 2017). The European Society of Cardiology state that reperfusion by PCI is indicated in patients with STEMI within 12 hours of symptom onset provided it can be performed within 120 minutes of diagnosis. For those patients unable to meet the targeted timeframes for PCI, the second line of reperfusion treatment is thrombolysis and should be performed within 10 minutes of STEMI diagnosis (Ibanez et al., 2017). With a growing trend for quick and effective reperfusion, PCI has evolved into the superior reperfusion strategy for STEMI. When compared to thrombolytic therapy, PCI shows reduced numbers of stroke, reinfarction and death (Keeley, Boura, & Grines, 2003). With the movement toward PCI, early activation of the cardiac catheterisation laboratory based on prehospital ECG diagnosis is seen as one of the cornerstones for early therapy around the world and can decrease the time to reperfusion by up to 60 minutes (Ducas et al., 2012; Garvey, MacLeod, Sopko, & Hand, 2006).

The American Heart Association (AHA) recommends that for optimal care, ambulance service organisations should provide an ambulance officer capable of providing diagnosis and direct transport to the nearest cardiac catheterisation laboratory. The AHA further recommends that transport time to a cardiac catheterisation laboratory be less than 90 minutes for at least 75% of all transported patients with STEMI (Antman et al., 2008). Despite the many recommendations, the availability of PCI in high-income economies is still only available within this timeframe for 15 to 20% of patients with

STEMI. The exceptions are where 24-hour catheter facilities exist. Here, the PCI rate in STEMI patients can be up to 80% (Huber et al., 2005).

First medical contact with triage by an ambulance officer is seen as an important factor within a system of care for those with suspected STEMI (Ibanez et al., 2017). In the United States of America, it was reported that only one-quarter of patients with STEMI transported by ambulance will receive a prehospital ECG, therefore, reducing the ability for early identification of STEMI (Diercks et al., 2009). Performance of a 12-lead ECG for patients with suspected STEMI is recommended by the European Society of Cardiology and helps identify the presence of an acute STEMI and promote prompt revascularisation. This is a Class I recommendation, indicating that it is supported by evidence and/or agreement that the procedure is effective, useful, or beneficial (Ibanez et al., 2017).

To enable appropriate hospital bypass for early PCI within the prehospital environment, diagnostic 12-lead ECG's must be performed. Additional benefits to a strategy of autonomous prehospital 12-lead ECG interpretation include; avoidance of inter-hospital transfer where patients might otherwise present to a non-interventional facility (Scholz et al., 2008), improved resource utilisation with accurate activation of catheterisation laboratory, and improved patient safety (Ducas et al., 2012).

In Australia, prehospital 12-lead ECG acquisition has resulted in a significant reduction in the mean door-to-balloon time for STEMI patients undergoing PCI: down from 100 minutes to 54 minutes (Hutchison, Malaiapan, Cameron, & Meredith, 2013). Those STEMI cases achieving door-to-balloon of ≤90 minutes was significantly greater when the first 12-lead ECG was performed prehospitally when compared to hospital (90% versus 42%, $p = 0.001$) (Hutchison et al., 2013). There is potential therefore to substantially reduce door-to-balloon (PCI) and door-to-needle (fibrinolytic) time with routine prehospital 12-lead ECG for patients with cardiac symptoms (Adams et al., 2010; Rao et al., 2010).

1.6 Prehospital STEMI

Whilst there is international evidence that ambulance officers can recognise STEMI based on a 12-lead ECG, further studies are required to determine if this finding fits the New Zealand context. When considering the importance of 12-lead ECG interpretation of STEMI by an ambulance officer, there is an increased emphasis on the quality,

performance, and systems of care within the prehospital environment (Travers, Rea, Bobrow, Edelson, & Berg, 2010). There is a responsibility at an organisational level to invest in a process of quality improvement that should provide a system of support and maintenance of standards. This should include 1) the continuous measurement of myocardial infarct management and outcome. 2) An internal and external benchmark review of the performance data and 3) an organisational strategy that identifies issues and addresses deficits (Travers et al., 2010).

For a system of care to be successful, there must be optimal diagnostic competency with low false-negative and low false-positive rates of STEMI diagnosis (Ringstrom & Freedman, 2006). The system must provide a balance between the potential financial cost implications for inappropriate activation of hospital resources and importantly, the risk of missing the STEMI diagnosis (Nolan et al., 2015). Non-physicians trained in 12-lead ECG interpretation may well be key to the overall efficacy of this system (Fukuoka et al. 2007).

The criteria for the diagnosis of an acute, evolving, or recent myocardial infarction relates to a formula first outlined by the World Health Organisation in 1979 (Bernard, 1979). The formula required two or more criteria to be satisfied for a diagnosis to be made.

- Serial ECG changes
- Creatine Kinase-MB fraction and troponin serum biomarkers that show a rise and fall
- More than 20 minutes of chest pain

This formula advocated that a diagnosis of myocardial infarction was ‘probable’ if two criteria are met and ‘definite’ if three. The World Health Organisation criteria were later revised as it was thought that there was too little an emphasis on cardiac biomarkers. The most current criteria suggest a cardiac troponin rise in addition to either ST elevation or depression, typical symptoms, or pathological Q-waves (Thygesen et al., 2012); Table 2.

Table 2 *Third Universal Definition of Myocardial Infarction*

Definition of myocardial infarction

Criteria for acute myocardial infarction

The term acute myocardial infarction should be used when there is evidence of myocardial necrosis in a clinical setting consistent with acute myocardial ischemia. Under these conditions, any one of the following criteria meets the diagnosis for myocardial infarction:

- Detection of a rise and/or fall of cardiac biomarker values (preferably cardiac troponin) with at least one value above the 99th percentile URL and with at least one of the following: (i) symptoms of ischemia, or (ii) new or presumed new significant ST-segment–T wave (ST–T) changes or new left bundle branch block, or (iii) development of pathological Q waves in the electrocardiogram, or (iv) imaging evidence of new loss of viable myocardium or new regional wall motion abnormality, or (v) identification of an intracoronary thrombus by angiography or autopsy.
- Cardiac death with symptoms suggestive of myocardial ischemia and presumed new ischemic electrocardiographic changes or new left bundle branch block, but death occurred before cardiac biomarkers were obtained, or before cardiac biomarker values would be increased.
- Percutaneous coronary intervention related myocardial infarction is arbitrarily defined by elevation of cardiac troponin values (>5×99th percentile URL) in patients with normal baseline values (≤99th percentile URL) or a rise of cardiac troponin values >20% if the baseline values are elevated and are stable or falling. In addition, either (i) symptoms suggestive of myocardial ischemia, or (ii) new ischemic electrocardiographic changes, or (iii) angiographic findings consistent with a procedural complication, or (iv) imaging demonstration of new loss of viable myocardium or new regional wall motion abnormality are required.
- Stent thrombosis associated with myocardial infarction when detected by coronary angiography or autopsy in the setting of myocardial ischemia and with a rise and/or fall of cardiac biomarker values with at least one value above the 99th percentile URL.
- Coronary artery bypass grafting related myocardial infarction is arbitrarily defined by elevation of cardiac biomarker values (>10×99th percentile URL) in patients with normal baseline cardiac troponin values (≤99th percentile URL). In addition, either
  - (i) new pathological Q waves or new left bundle branch block, or
  - (ii) angiographic documented new graft or new native coronary artery occlusion, or
  - (iii) imaging evidence of new loss of viable myocardium or new regional wall motion abnormality.

Criteria for prior myocardial infarction

Any one of the following criteria meets the diagnosis for prior myocardial infarction:

- Pathological Q waves with or without symptoms in the absence of non-ischemic causes.
- Imaging evidence of a region of loss of viable myocardium that is thinned and fails to contract, in the absence of a non-ischemic cause.
- Pathological findings of a prior myocardial infarction.

Note. Reprinted with permission from *European Heart Journal*, by Thygesen, K., Alpert, J. S., Jaffe, A. S., Simoons, M. L., Chaitman, B. R., White, H. D., . . . Alpert, J. S. (2012). Third universal definition of myocardial infarction. *European Heart Journal, 33*(20), 2551-2567. (Appendix C).

With consensus advocating that a diagnosis of acute, evolving, or recent myocardial infarction meet the criteria found in Table 2, there are aspects that are currently difficult to achieve within the prehospital environment. Point-of-care cardiac biomarker testing is expensive and currently unavailable within a New Zealand ambulance service (Kip, Koffijberg, Moesker, IJzerman, & Kusters, 2017). Whilst emphasis has been placed on cardiac biomarkers, it is important to evaluate the current system on its merits rather than the availability of emerging technology. For this reason, St John ambulance service within New Zealand and within the context of this thesis, follow criteria comparable to the World Health Organisation guideline (Appendix D).

Whilst there is some disparity and variance, the international emphasis placed on prehospital STEMI diagnosis shows an increased number of patients being diagnosed and transported by an ambulance officer. To provide context, ambulance services in the United Kingdom transported 85% of STEMI patients (Pilbery, Teare, Goodacre, & Morris, 2016), with the remainder self-presenting at hospital. Corresponding figures for the United States of America report transportation of 60% of patients with STEMI (So et al., 2006). The increasing trend toward a system of care that includes ambulance officer autonomous interpretation of STEMI is a key factor when trying to determine prehospital diagnosis.

The ability of an ambulance officer to identify prehospital STEMI when compared to a cardiologist was found to show high levels of ambulance officer false-positive diagnosis (Huitema, Zhu, Alemayehu, & Lavi, 2014). False-positive diagnosis occurs when the ambulance officer forms a clinical impression of STEMI when in fact, the patient does not have this condition. These findings have the potential for inappropriate activation of the cardiac catheterisation laboratory or incorrect administration of prehospital thrombolytic therapy (Tanguay et al., 2017). With the uncertain and unpredictable nature of the prehospital clinical environment, it is important to understand how this relates to the Auckland setting.

1.7 The Auckland STEMI System

In 2016 New Zealand ambulance guidelines recommended that prehospital 12-lead ECGs are to be performed on all patients with cardiac symptoms. Within the context of this study, and within the Auckland region, if the 12-lead ECG meets the STEMI criteria (Figure 1) it is electronically transmitted to the hospital for Emergency Department consultant review. This is an autonomous act under protocol guidance. The

consultant will then arrange appropriate treatment options for the patient prior to ambulance arrival at the emergency department. Alternatively, the consultant may advise the ambulance to bypass the nearest hospital in favour of direct transport to a specialist centre with interventional facilities (Appendix D.). Incorporation of a bypass protocol has the potential to reduce time to intervention significantly (Bagai et al., 2013; Batt et al., 2018).

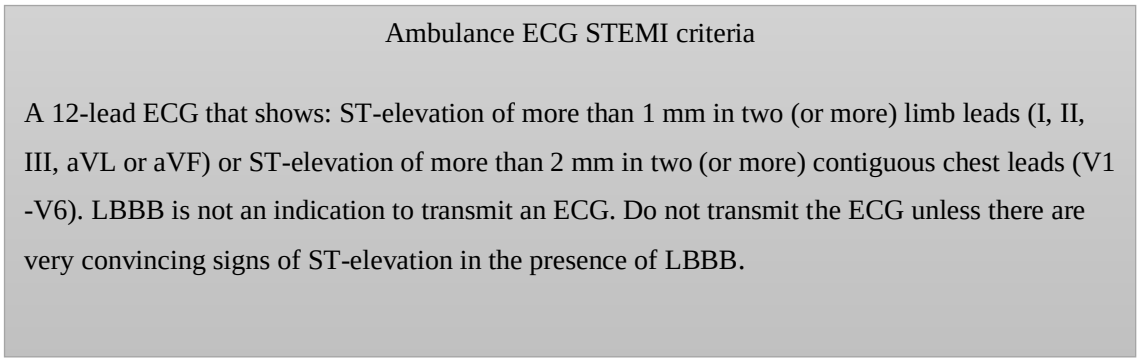


Figure 1 St John ECG STEMI Criteria.

Note. Reprinted with permission from the Auckland Ambulance STEMI flow chart (2012) by St John. Smith, T. Auckland Ambulance STEMI flow chart May 2015. St John. (Appendix E). LBBB = Left bundle branch block.

Within the Auckland region, early activation of the catheter laboratory relies on the ambulance officer being able to accurately identify the STEMI. Failure to recognise a STEMI has the potential to delay access to early definitive treatment, which in turn influences outcome and mortality (Li et al., 2015). The ability to accurately interpret the prehospital 12-lead ECG is therefore pivotal (Ayer & Terkelsen, 2014). Although the international literature identifies diagnostic accuracy, there is currently no performance benchmark or evaluation of prehospital STEMI diagnosis within the New Zealand context.

1.8 Study Aims

The primary aim of this thesis is to investigate whether those patients with STEMI can be recognised as having STEMI by ambulance officers compared with confirmed hospital diagnosis of STEMI (Confirmed final hospital diagnosis of STEMI with the requirement for treatment by PCI or thrombolytic therapy). The secondary aim is to identify predictors of ambulance and hospital diagnostic agreement. This includes patient demographics, ambulance service operational factors and clinical management compliance.

1.9 Thesis Structure

This thesis consists of six chapters that represent research carried out with St John Ambulance service within the Auckland region. It examines the accuracy of STEMI diagnosis by ambulance officers when compared with final hospital diagnosis and identifies predictors of ambulance and hospital diagnostic agreement. Chapter 1 has described the rationale for this study and background to the burden of cardiac disease both internationally and within a New Zealand context. Implementation of international STEMI guidelines to improve patient outcome have also been explored. The thesis structure is outlined in Figure 2.

Chapter 2 follows 'Preferred Reporting Items for Systematic Reviews and Meta-Analyses' (PRISMA) methodology to provide a structured semi-systematic review of the literature that focuses on the accuracy of prehospital STEMI diagnosis by the ambulance officer.

Chapter 3 describes the Methods used to evaluate the data. STrengthening the Reporting of OBservational Studies in Epidemiology (STROBE) guidelines are used. Variables including participant characteristics and settings are provided.

Chapter 4: The hospital STEMI diagnosis is compared to the ambulance officer diagnosis to determine the accuracy of the prehospital diagnosis of STEMI. This chapter provides a formative investigation of the main results that include descriptive data, patient demographics, ambulance service operational factors and clinical management compliance. STROBE is used to interpret and report the information (Vandenbroucke et al., 2014).

Chapter 5 provides a summary of the key findings in relation to the research question. Analysis of significance and contribution to practice are discussed. Characteristics of design or methodology limitations, generalisability and future implications to current practice are discussed.

Chapter 6 offers final statements and the conclusion.

Auxiliary material including a glossary of terms.

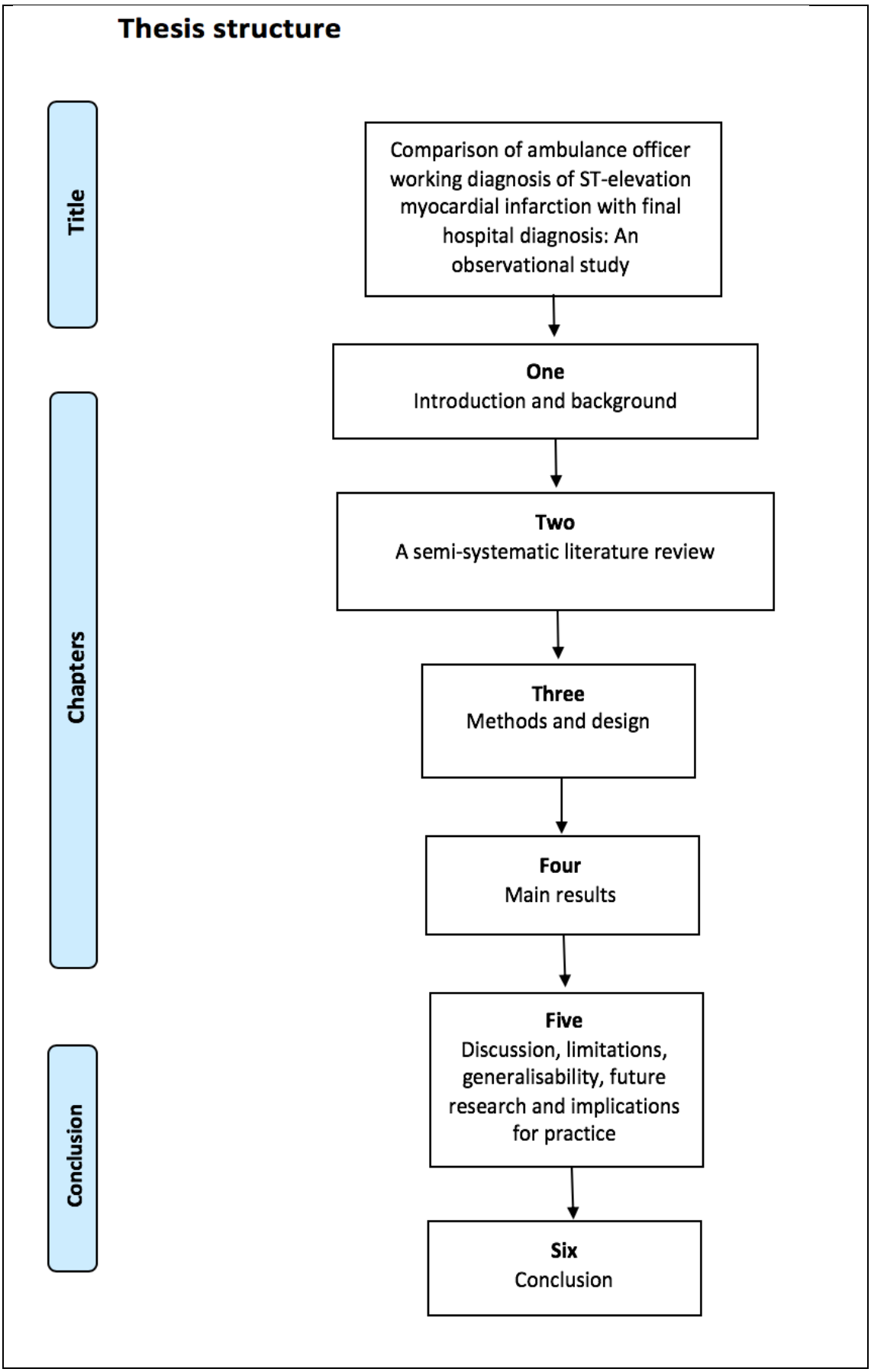


Figure 2 Thesis Structure

Chapter 2 LITERATURE REVIEW

2.1 Introduction

Chapter 1 showed the importance of the acquisition and interpretation of a 12-lead ECG for triage, diagnosis, and initiation of early treatment for those with suspected STEMI. Also outlined in Chapter 1 are acute myocardial infarction and STEMI in relation to ambulance service prehospital care and the aims of the thesis. The primary aim of this thesis is to investigate whether (P) patients with STEMI (I) can be recognised as having STEMI by ambulance officers (C) compared with confirmed hospital diagnosis of STEMI (O) the outcome is the accuracy of diagnosis. The secondary aim is to identify predictors of ambulance and hospital diagnostic agreement.

In this chapter, I will follow a PRISMA methodology to provide a semi-systematic review of the literature to investigate whether those patients with STEMI can be recognised as having STEMI by an ambulance officer. There is evidence that ambulance officers can establish a working diagnosis of STEMI based on the 12-lead ECG in conjunction with the clinical presentation. Accurate diagnosis is crucial in order to provide appropriate transport and treatment. However, there is considerable heterogeneity in the accuracy reported internationally and no data is available within the New Zealand context.

I will begin by outlining the literature review methods, evidence appraisal, results and design of the review. The subsequent sections appraise topics and key themes investigated and include; 1) ambulance officer STEMI diagnostic accuracy and the sensitivity of ambulance officer diagnosis. 2) the effect of STEMI mimic on diagnosis, 3) predictors of ambulance officer STEMI diagnosis.

2.1.1 Literature Review Objective

Within a PICO framework, a literature search was conducted to identify studies that explored ambulance officer STEMI diagnosis by 12-lead electrocardiogram. The primary aim was to investigate whether (P) patients with STEMI (I) can be recognised as having STEMI by ambulance officers (C) compared with confirmed hospital diagnosis of STEMI (O) the outcome was the accuracy of diagnosis. The secondary aim was to identify predictors of ambulance and hospital diagnostic agreement.

2.2 Method of the Literature Review

The Electronic databases Medline, Scopus, Cochrane, and the Biomedical reference collection (EBSCO and OVID) were searched using the key terms ‘EMS’ OR ‘Ambulance’ OR ‘Paramedic’ AND ‘STEMI’ AND ‘Recognition’ AND ‘Accuracy’ AND ‘Diagnosis’ AND ‘ECG’ OR ‘12 lead’ OR ‘Electrocardiogram’. Articles describing STEMI diagnosis by paramedics were eligible for inclusion. The term paramedic and ambulance officer were interchangeable and were generic terms used for this search.

This literature review was limited to peer-reviewed papers. Addition limits included those of English language only, full-text journal articles and date of publication between 2005 and 2018. Since 2000, the International Liaison Committee on Resuscitation (ILCOR) has published the International Consensus on Cardiopulmonary Resuscitation and Emergency Cardiovascular Care Science with Treatment Recommendations every five years based on a review of cardiopulmonary resuscitation science (Olasveengen et al., 2017). This formed the basis of the date range used.

An online search of grey literature such as non-governmental and government organisations was conducted. The abstracts and titles of all identified papers were screened for relevance. Full texts were subsequently retrieved and reviewed for relevance. The study quality was appraised by evaluating the study design elements. Finally, the search strategy was saved and repeated to allow for updates of published material.

The literature search followed a non-peer reviewed PRISMA methodology to provide a semi-systematic review of the literature (Moher, Liberati, Tetzlaff, & Altman, 2010). For each article, the reference list was reviewed to identify any relevant or unidentified articles that were not selected in the main search strategy selection process. Figure 3 below provides an overview of the search process. This includes database used and exclusion criteria.

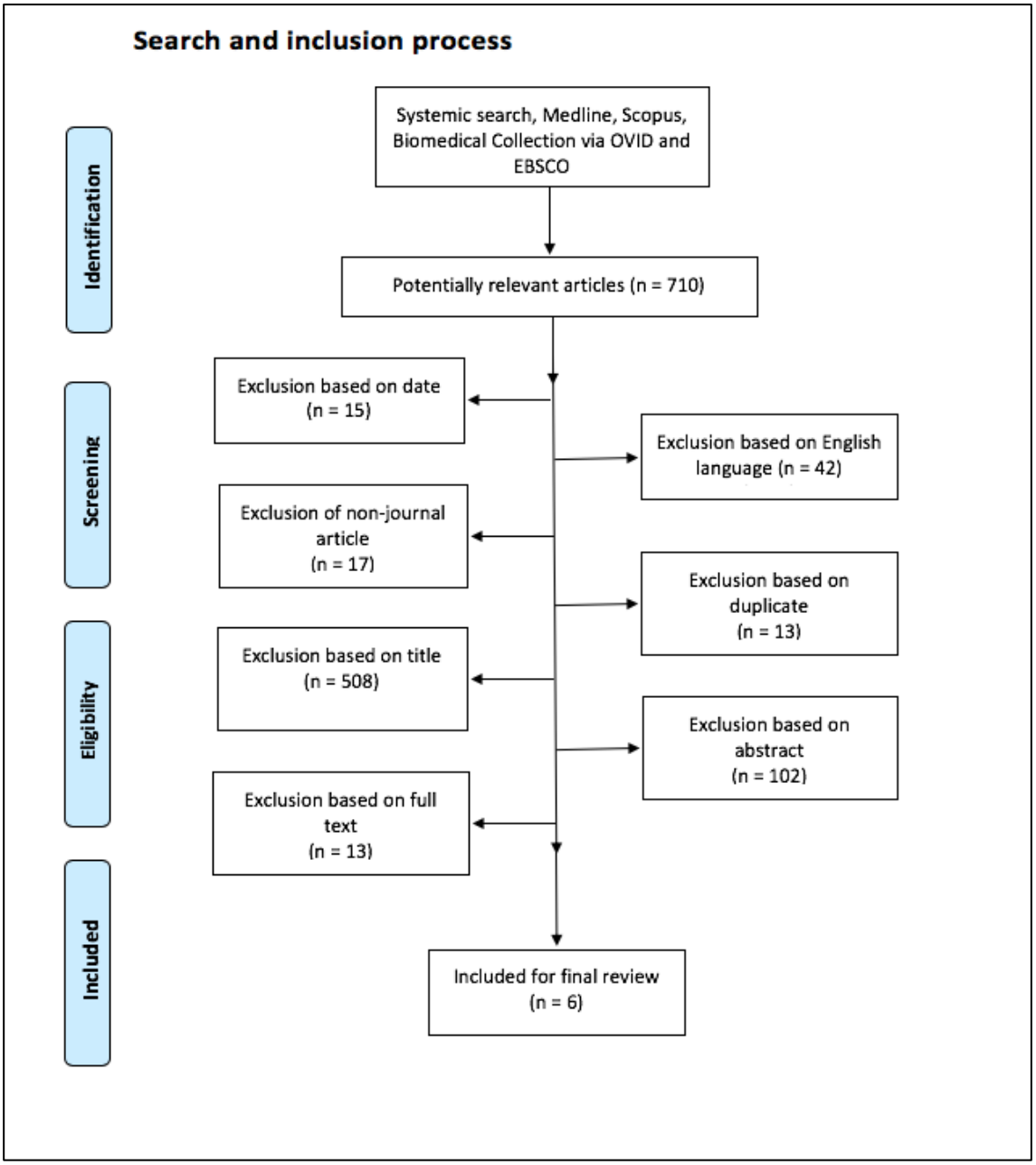


Figure 3 Literature Search and Inclusion Process

2.3 Evidence Appraisal

The reviewed studies were classified by level (quality) of evidence (LOE) based on the American Cardiovascular Care /American Heart Association Clinical Practice recommendation classification system: Table 3. Quality was rated within five focused criteria. They were High, Moderate (randomized), Moderate (non-randomised), Limited data and Expert opinion (Halperin et al., 2016).

Table 3 *American Cardiovascular Care Classification System*

Level (quality) of evidence	
Level A	• High-quality evidence‡ from more than 1 RCTs • Meta-analyses of high-quality RCTs • One or more RCTs corroborated by high-quality registry studies
Level B-R (Randomized)	• Moderate-quality evidence‡ from 1 or more RCTs • Meta-analyses of moderate-quality RCTs
Level B-NR (Nonrandomized)	• Moderate-quality evidence‡ from 1 or more well-designed, well-executed nonrandomized studies, observational studies, or registry studies • Meta-analyses of such studies
Level C-LD (Limited Data)	• Randomized or nonrandomized observational or registry studies with limitations of design or execution • Meta-analyses of such studies • Physiological or mechanistic studies in human subjects
Level C-EO (Expert Opinion)	• A consensus of expert opinion based on clinical experience

The American Cardiovascular Care /American Heart Association Clinical Practice recommendation classification system aligns scientific evidence with patient care (Jacobs et al., 2013). The quality and level of evidence outlined within the system indicate the certainty of and confidence in, research findings. The level of evidence is in general terms prioritised by order, with randomised trials providing a higher level of evidence than that of retrospective or observational studies.

High-quality Level A evidence requires two or more sufficiently powered randomised trials or meta-analyses of high-quality trials. In addition, high-quality registry corroboration of randomised trial data also qualifies. Level of evidence B is based on meta-analyses of moderate quality trials, registry derived data or those that have had no external validation of source material. Those at level B are further divided into those that are randomised (B–R) or non-randomised studies (B-NR). Level B is of less convincing evidence or moderate quality. When strong scientific support is not available for a recommendation, level of evidence C is appointed. This has two subcategories, those with limited data (C-LD), and those that are based on expert opinion or clinical experience (C-EO); Table 3.

2.4 Literature Review Results

The search identified a total of 710 potentially relevant papers; Figure 3. After exclusion based on English language, date, full text, and duplicates, 108 articles were retained. After reviewing the abstracts, a further 102 articles were excluded as they did not provide a direct comparison of prehospital ambulance officer ECG STEMI interpretation with confirmed end diagnosis. This resulted in six articles being included in the review; Table 4.

Table 4 *Full Paper Review Articles*

Authors	Country	Sample size	Enrolment dates
Davis, D. P., Graydon, C., Stein, R., Wilson, S., Buesch, B., Berthiaume, S., ... & Leahy, D. R. (2007).	United States of America	n=110	Nov 2003 – Dec 2005
Ducas, R. A., Wassef, A. W., Jassal, D. S., Weldon, E., Schmidt, C., Grierson, R., & Tam, T. W. (2012).	Canada	n=703	July 2008 – July 2010
Feldman, J. A., Brinsfield, K., Bernard, S., White, D., & Maciejko, T. (2005).	United States of America	n=166	May 1997 – Dec 1997
Le May, M. R., Dionne, R., Maloney, J., Trickett, J., So, D., ... & Davies, R. F. (2006b).	Canada	n=967	July 2003 – June 2004
Mencl, F., Wilber, S., Frey, J., Zalewski, J., Maiers, J. F., & Bhalla, M. C. (2013).	United States of America	n=472	July 2010 – Jan 2011
Trivedi, K., Schuur, J. D., & Cone, D. C. (2009).	United States of America	n=103	No date range

2.5 Designs of included Studies

There were no randomised controlled trials, or meta-analyses (LOE A or LOE B-R). Three prospective observational studies (LOE B-NR) (Davis et al., 2007; Ducas et al., 2012; Feldman, Brinsfield, Bernard, White, & Maciejko, 2005) and three (level C) limited data studies were identified (Le May et al., 2006b; Mencl et al., 2013; Trivedi, Schuur, & Cone, 2009). All six studies required the ambulance officer to identify STEMI by analysing a 12-lead ECG. All but one study (Mencl et al., 2013), provided additional training or a refresher course prior to the research. Four studies (Davis et al., 2007; Ducas et al., 2012; Feldman et al., 2005; Le May et al., 2006b) compared 12-lead interpretation by the paramedic with that of an emergency physician/cardiologist. The remaining two studies (Mencl et al., 2013; Trivedi et al., 2009), provided printed ECG test scenarios for evaluation. Only three studies, (Davis et al., 2007; Ducas et al., 2012; Le May et al., 2006b) looked at actual patient-based clinical practice, Table 5.

Table 5 *Evidence Supporting, Neutral or Opposing Ambulance Officer STEMI* Diagnosis

Level of evidence	**A**	**B-R**	**B-NR**	**C-LD**	**C-EO**
Evidence supporting STEMI diagnosis			Ducas et al (2012) Feldman et al (2004)	Trivedi et al (2009) Le May et al (2006b)	
Evidence neutral to STEMI diagnosis			Davis et al (2007)		
Evidence opposing STEMI diagnosis				Mencl et al (2013)	

The ability of the ambulance officer to identify STEMI was reported by four of the six studies (Ducas et al., 2012; Feldman et al., 2005; Le May et al., 2006b; Trivedi et al., 2009). Davis et al. (2007) advocated a system of 12-lead ECG transmission for improved ambulance officer STEMI diagnosis. Despite high levels of confidence and training, Mencl et al. (2013) reported contradictory data showing ambulance officers 12-lead ECG interpretation is unreliable and requires further investigation. Table 6 below summarises the key findings, study protocol, sample size, health provider types, and the amount of additional refresher training provided.

Table 6 *Summary of Studies Describing Prehospital STEMI Diagnosis*

Authors	Healthcare profession	Hours of training	Study design/protocol	Sample size	Key findings	Results
Davis, D. P., Graydon, C., Stein, R., Wilson, S., Buesch, B., Berthiaume, S., ... & Leahy, D. R. (2007).	Paramedics and Doctors	3	Prospective observational study. For the first year, the STEMI catheterisation laboratory was activated by paramedics (Phase I). After the first year, the ECG was transmitted to the ED, with the emergency physician (EP) responsible for activation (Phase II).	n=110	Transmission of the ECG to hospital for Doctor interpretation improves the positive predictive value of the prehospital 12-lead ECG for triage and therapeutic decision-making.	Phase I reported 78% paramedic accuracy. Phase II reported an increased accuracy of 96% with Doctor interpretation.
Ducas, R. A., Wassef, A. W., Jassal, D. S., Weldon, E., Schmidt, C., Grierson, R., & Tam, J. W. (2012)	Paramedics and Doctors	21	Prospective observational cohort study. Paramedic transmission of suspected STEMI with confirmation by Doctor. Study patients were divided into 2 groups: (1) patients with a non-transmitted ECG due to interpretation as negative for STEMI by the paramedic and (2) patients with a transmitted ECG to a doctor with suspicion of STEMI by the paramedic. The primary outcome measures were the positive and negative predictive values of prehospital ECG interpretation by the paramedic.	n=703	Non-physician interpretation of STEMI on prehospital ECG has excellent sensitivity and high negative predictive value. This finding supports the use of prehospital ECGs interpreted by paramedics to help identify and facilitate treatment of STEMI.	Paramedic ECG interpretation for STEMI reported 99% sensitivity (95% CI, 97 to 99), 67% specificity (95% CI, 63 to 72), NPV of 99.6% (95% CI, 98 to 99) and PPV of 60% (95% CI, 54 to 64), with an overall accuracy of 78% (95% CI, 75 to 81).

Authors	Healthcare profession	Hours of training	Study design/protocol	Sample size	Key findings	Results
Feldman, J. A., Brinsfield, K., Bernard, S., White, D., & Maciejko, T. (2005).	Paramedics and Doctors	6	Prospective observational study to determine if paramedics can accurately identify STEMI on prehospital 12-lead electrocardiogram and to compare paramedic with blinded physician identification of STEMI. Two blinded readers (cardiologist and emergency physician) independently categorized each 12-lead electrocardiogram. A third reviewer assigned final diagnoses and determined whether the 12-lead electrocardiogram met STEMI criteria.	n=166	Paramedics can accurately and specifically identify STEMI. Paramedics without online physician review may be sufficiently accurate to allow triage of selected patients with AMI to catheterization centres, provision of prehospital thrombolysis, or mobilization of interventional teams.	Paramedic performance reported sensitivity 80% (95% CI, 64 to 96), specificity 97% (95% CI, 94 to 100), NPV 83% (95% CI, 68 to 98), PPV 96% (95% CI, 93 to 99), and overall accuracy of 94% for diagnosis of STEMI (95% CI, 90 to 98).
Le May, M. R., Davies, R. F., Dionne, R., Maloney, J., Trickett, J., So, D., ... & O'Brien, E. R. (2006b).	Paramedics and Doctors	8[a]	Pilot study STEMI tool. Two emergency physicians and one cardiologist, blinded to the paramedic' tool report, independently reviewed all the prehospital ECGs and patients' charts to evaluate the diagnoses, using the same diagnostic tool criteria.	n=411	Paramedics can be trained to use a tool to accurately interpret the prehospital ECG for the diagnosis of STEMI.	Paramedic performance reported sensitivity 95% (95% CI, 86 to 99), specificity 96% (95% CI, 94 to 98), PPV 82% (95% CI, 71 to 90), NPV 99% (95% CI, 97 to 100) for diagnosis of STEMI.

Authors	Healthcare profession	Hours of training	Study design/protocol	Sample size	Key findings	Results
Mencl, F., Wilber, S., Frey, J., Zalewski, J., Maiers, J. F., & Bhalla, M. C. (2013).	Paramedics	0	Descriptive cohort study using a survey administered to paramedics. The survey contained questions about training, experience, and confidence, along with 10 ECGs: three demonstrating STEMIs (inferior, anterior, and lateral), two with normal results, and five STEMI mimic.	n=472	No correlation between training, experience, or confidence and accuracy in recognizing STEMIs. Paramedic only able to identify an inferior STEMI and two normal ECGs. Cannot rely solely on their ECG interpretation to activate the cardiac catheterization laboratory.	The overall sensitivity and specificity for STEMI detection were 75% (95% CI, 73 to 77) and 53% (95% CI, 51 to 55), respectively.
Trivedi, K., Schuur, J. D., & Cone, D. C. (2009)	Paramedics	1	Five case vignettes were presented in a random order to a convenience sample group. Each case was accompanied by a standardized computer-generated 12-lead ECG that either was normal or showed STEMI. Each scenario was followed by two yes/no questions: 1) "Acute STEMI?" and 2) "Immediate Cath Lab Activation?"	n=103	Paramedics in an urban/suburban EMS system can diagnose STEMI on a prehospital 12-lead ECG and identify appropriate cardiac catheterization laboratory activations with a high degree of accuracy, and an acceptable false-positive rate when tested using paper-based scenarios.	Paramedic STEMI diagnostic sensitivity was 92% (95% CI, 88 to 95) and specificity 85% (95% CI, 79 to 89).

Note .[a] plus, written ECG examination. ED = Emergency Department; ECG = Electrocardiograph; NPV = Negative predictive value; PPV = Positive predictive value; CI = Confidence interval

2.6 Ambulance Officer STEMI Diagnosis

Prehospital 12-lead ECG interpretation remains the most sensitive early indicator of STEMI in patients with symptoms of acute coronary ischemia (Hemsey, Dracup, Fleischmann, Sommargren, & Drew, 2012). The ability to interpret 12-lead ECG in the field confers advantages that may help to bolster international guideline recommendations for STEMI management. Furthermore, a 12-lead ECG may enable early identification, triage, treatment, and subsequent direct transport to a PCI capable facility for those with STEMI. The heterogeneity of reported methodologies, metrics, advanced training programs, mimic exclusion and limited real-time studies within the literature make it problematic to definitively determine the accuracy of ambulance officer prehospital STEMI diagnosis. Whilst early triage and diagnosis of STEMI in the prehospital setting are possible, the current level of accuracy within New Zealand was not established.

International literature has sought to investigate ambulance officer 12-lead ECG diagnostic accuracy with differing results. An investigation into the diagnostic accuracy in a prospective observational cohort study of real-world ambulance officer STEMI interpretation was carried out by Ducas et al. (2012). Ambulance officer interpretation of 12-lead ECG when looking for STEMI highlight a 99% sensitivity (95% CI, 97 to 99), 67% specificity (95% CI, 63 to 72), NPV of 99% (95% CI, 98 to 99) and PPV of 60% (95% CI, 54 to 64), with an overall accuracy of 78% (95% CI, 75 to 81). A pilot study by Le May et al. (2006b) had similar findings following 12-lead ECG interpretation of 411 patients with chest pain by ambulance officers. Here the sensitivity and specificity were 95% (95% CI, 86 to 99), and 96% (95% CI, 94 to 98) respectively, with a PPV 82% (95% CI, 71 to 90) and a NPV 99% (95% CI, 97 to 100). Similarly, Ducas et al. (2012) and Le May et al. (2006b) concluded that their high sensitivity and specificity results support acceptable 12-lead ECG interpretation accuracy by ambulance officers.

The ability to recognise STEMI with a level of added complexity was investigated by Mencl et al. (2013). The investigators required ambulance officers to review 10 predetermined 12-lead ECGs and identify STEMI. Here, a variety of 12-lead ECG was included: two normal sinus rhythm ECGs, three STEMI, four STEMI mimics and one supraventricular tachycardia. The overall sensitivity and specificity were 75% (95% CI, 73 to 77) and 53% (95% CI, 51 to 55) respectively, with the ambulance officer able to

identify the majority of the normal sinus rhythm ECG: 97% (95% CI, 95 to 99). Identification of STEMI by coronary vessel location had less consistent results; Inferior STEMI: 96% correct (95% CI, 94 to 99), anterior STEMI: 78% correct (95% CI, 74 to 82) and lateral STEMI: 51% correct (95% CI, 46 to 56). The authors concluded that a reduction in 12-lead ECG STEMI accuracy when complexity is added promotes concern when interpreting the findings of Ducas et al. (2012) and Le May et al. (2006b).

Le May, Dionne, Maloney, and Poirier (2010) found ambulance officers had comparable 12-lead ECG STEMI accuracy to emergency physicians. This was pertinent as both healthcare professionals are primary treatment providers for patients with STEMI. The results show a false-positive rate for STEMI between 10% - 15% by ambulance officers, with rates for emergency physicians being almost identical (Le May et al., 2010). Whilst there is uncertainty to the question of prehospital ambulance officer STEMI diagnosis, this report shows that the ambulance officer can identify STEMI with false-positive rates comparable to other healthcare professionals.

Ambulance officers can identify STEMI as accurately as blinded cardiologist and emergency physicians (Feldman et al., 2005). In the study by Feldman et al. (2005), the cardiologist and emergency physician were blinded to patient presentation and could only view the 12-lead ECG with symptom data removed. The results from this study report ambulance officer STEMI interpretation as 94% accurate (95% CI, 90 to 98) with a sensitivity of 80% (95% CI, 64 to 96) and specificity of 97% (95% CI, 94 to 100). Cardiologist and emergency physician were comparable to the ambulance officer with a sensitivity of 95% (95% CI, 92 to 99) and specificity of 93% (95% CI, 89 to 97). However, the exclusion of patient symptom information for the cardiologist/emergency physician limits true comparison with the ambulance officer. Patient symptom information may provide a wider clinical picture and offer additional risk in accord with a diagnosis of STEMI.

The removal of realistic real-world influences when investigating clinical decision-making somewhat limits our understanding of ambulance officer STEMI accuracy. Compared with the provision of out-of-hospital real-world diagnosis complexity, paper-based scenarios such as those by Trivedi et al. (2009) offer a safe and controlled environment. It would, therefore, be reasonable to suggest that without the complexity of real-time 12-lead ECG interpretation and symptom investigation, the ability to recognise STEMI is undoubtedly made less complex. This may impact our

understanding of clinical judgement and decision making in the unpredictable patient presentation (Croskerry, 2002). Whilst there is a statistical lean toward advocating that ambulance officers can identify STEMI, there are additional factors and influences such as STEMI mimics that will first need to be reviewed.

2.6.1 Effect of STEMI Mimics on Diagnosis

There are many medical conditions that can produce ST-segment elevation but are not as a result of an AMI (Shams et al., 2016). A non-ischaemic cause of ST- elevation is known as a STEMI mimic. STEMI mimic presentation can confuse a clinical diagnosis, therefore, as part of standard 12-lead ECG investigation for STEMI, STEMI mimics need to be considered. There are several common 12-lead ECG mimics of STEMI within clinical practice. These are left bundle branch block, right bundle branch block, left ventricular hypertrophy, myocarditis, ventricular pacing, coronary vasospasm (Prinzmetal's angina) and early repolarisation changes (Shams et al., 2016). STEMI mimics, therefore, can be difficult to identify and may influence the ability to provide an accurate diagnosis (Mencl et al., 2013).

When performance of ambulance officer STEMI diagnosis is investigated, common STEMI mimics are often excluded (Ducas et al., 2012; Feldman et al., 2005; Le May et al., 2006b; Trivedi et al., 2009). The exception to this was a prospective observational study of prehospital ambulance officer STEMI diagnosis reported by Davis et al. (2007). Phase one, relied on the ambulance officers' clinical suspicion of AMI, plus the addition of a 12-lead ECG to help determine STEMI. The (subsequent) phase two stage required an ambulance officer to transmit the prehospital 12-lead ECG and gain confirmation of STEMI diagnosis by a hospital doctor. This data was recorded by way of a hospital cardiac alert activation log following ambulance officer 12-lead ECG electronic transmission. Phase one resulted in 78% STEMI accuracy and phase two 96% (OR 0.13, 95% CI, 0.03 to 0.61, $p = 0.001$) (Davis et al., 2007). This research allowed real-world interpretation and did not reduce the amount of complexity by removing STEMI mimics.

There were limitations to the data collection process used by Davis et al. (2007). Only cases recorded within the cardiac alert activation logbook and recorded as STEMI by the ambulance officer were included. Regardless of phase, the system required the ambulance officer to firstly identify a patient thought to have a STEMI prior to transmission of the 12-lead ECG. Phase two, whereby a doctor confirms or refutes the

initial diagnosis offered a greater level of accuracy but provided no estimation of false-negative diagnoses. There are two further limitations with this method. Firstly, it is unknown if the ambulance officer missed a STEMI (false-negative) resulting in the non-transmission of the 12-lead ECG. Secondly, it is unknown as to why the false-positive rate (incorrect diagnosis of STEMI) varied so greatly between the two phases: (phase 1) 22% false positive versus 8% false positive (phase 2).

With the inclusion of STEMI mimic, it is possible that in practice, ambulance officers may have reduced diagnostic accuracy in the field (Mencl et al., 2013). A descriptive cohort study by Mencl et al. (2013), found identification of STEMI mimic fared poorly when trying to establish 12-lead ECG interpretation: Right bundle branch block: 79% correct (95% CI, 75 to 82), left bundle branch block: 39% correct (95% CI, 35 to 44), ventricular pacing: 52% correct (95% CI, 48 to 57) and left ventricular hypertrophy: 36% correct (95% CI, 32 to 41). Supraventricular tachycardia was reported as 65% correct (95% CI, 61 to 70) (Mencl et al., 2013). The author's findings of low levels of accuracy for anterior (78%: CI 74 to 81) and lateral STEMI (51%: CI 46 to 55) in addition to STEMI mimics further highlighted a potential concern. Ducas et al. (2012), Trivedi et al. (2009), Feldman et al. (2005), and Le May et al. (2006) all excluded common STEMI mimics from their research. Only Davis et al. (2007) and Mencl et al. (2013) investigated the accuracy of STEMI interpretation without removing STEMI mimics. The inclusion or exclusion of STEMI mimic within a study design, therefore may influence the evaluation of prehospital STEMI diagnosis.

2.7 Predictors of Ambulance Officer Diagnosis

There is a limited body of literature that helps to identify factors associated with ambulance officer STEMI diagnosis. Published studies are limited to reporting ambulance services as a mode of transport to hospital and highlight the need for a greater understanding. Within this review, a trend toward equipment complications and demographics emerged as predictors to diagnosis. Comparison of first medical contact retrieval location and initial clinical presentation were not reported.

A 12-lead ECG machine is capable of automated diagnosis and interpretation of STEMI. Many machines make use of artificial intelligence and pattern recognition software to assist the clinician with diagnosis. A missed diagnosis of STEMI was associated with automated machine 12-lead ECG diagnosis, where artefact or STEMI

mimic was present (Bosson et al., 2017). Reliance on machine diagnosis in the presence of artefact or mimic may influence the accuracy of prehospital diagnosis.

Ambulance officers who self-reported low levels of confidence for ECG interpretation were less likely to correctly interpret STEMI (Trivedi et al., 2009). However, the availability of previous ECGs was reported to improve ambulance officer accuracy and enhance confidence of STEMI diagnosis (O'Donnell et al., 2015). The limited evidence reflects the lack of research available to inform evidence-based practice.

There was no correlation between experience, confidence or training with accuracy of STEMI diagnosis (Mencl, 2013). Ambulance officer STEMI diagnostic accuracy by patient sex (male/female) or those (with/without) cardiac risk factors showed no relationship (Trivedi et al., 2009). Ambulance officer characteristics such as number of shifts worked, cardiac assessments or ECG training were not associated with higher STEMI diagnostic accuracy (Trivedi et al., 2009).

Much uncertainty still exists in the literature as to the accuracy of real-world ambulance officer STEMI diagnosis. The generalisability between the different countries add ambiguity due to a variety of systems and structures in place. Researchers frequently fail to distinguish between patient retrieval location, practising qualification, or clinical presentation as an influence to diagnosis. Therefore, little is known about what factors help predict accurate prehospital STEMI diagnosis or provide insight within the New Zealand context. A better understanding of prehospital STEMI predictors can be used to inform ambulance officer clinical guidelines and education curriculum for increased diagnostic sensitivity.

2.8 Limitations of Published Literature

A key component of ambulance officer 12-lead ECG diagnostic accuracy is an understanding of their education, training, and knowledge. To provide accurate autonomous 12-lead ECG interpretation, without ECG telemetry or oversight, ambulance officers must possess a range of skills and expertise. An understanding of the current state of affairs needs to be investigated to see if these requisites are present when interpreting 12-lead ECG.

Published literature on prehospital STEMI diagnosis and triage was almost exclusively focused on those provided with additional training. In terms of base knowledge, this

review highlights a limitation in the investigation of STEMI accuracy as all but one study (Mencl et al., 2013) provided an advanced focused 12-lead ECG STEMI training package. This training had potential to direct the ambulance officer toward common sources of misclassification or mimic; pericarditis, bundle branch blocks, early repolarising variant, pacemakers, and ventricular aneurysms. Those taking part in the research may have been influenced toward looking for STEMI as the prospective study topic remit was provided in advance. In addition, with pre-study training/education, it is possible that ambulance officers modified their behaviour as a direct consequence of being studied. This is known as the Hawthorne effect (Paradis & Sutkin, 2017). Five of the six studies within this literature review provided ECG interpretation training prior to their research, Table 7.

Table 7 *Additional Participant Education Refresher Hours*

Author	Hours of Training	Training type
Davis et al. (2007)	3	AMI specific training, with emphasis on ECG findings (undisclosed).
Ducas et al (2012)	21	ACS and STEMI management. 12-lead ECG interpretation.
Feldman et al. (2005)	6	Practical and written exam. Emphasis on pathophysiology of ACS, acquisition of 12-lead, ECG interpretation of AMI, STEMI, BBB, Ventricular aneurysm, pericarditis, early repolarisation variance.
Le May et al. (2006b)	8	STEMI diagnosis followed by an undisclosed number of supervision hours. Certified written examination in STEMI diagnosis.
Mencl et al. (2013)	0	No additional training.
Trivedi et al. (2009)	1	12-lead ECG interpretation focused on STEMI. Some had additional in-service training on ECG and STEMI, others did not.

Note. ACS = Acute coronary syndrome; AMI = Acute myocardial infarction; BBB = Bundle branch block.

To compound potential bias, ambulance officers can retain 12-lead ECG training knowledge for a period of up to 12 months (Whitbread et al., 2002). It may be an important factor when reviewing the literature results, that 12-lead ECG interpretation skills following educational training can be retained for an extended period. A small

team of 10 United Kingdom ambulance officers completed a two day 12-lead ECG course and were retested after one year. The results of this study showed a high level of retest accuracy when interpreting STEMI: 95% (95% CI, 53 to 100) (Whitbread et al., 2002).

Additional training, reduced complexity and modified behaviour may have biased results so that the ambulance officer achieved a higher standard of accuracy than usual practice. This represents a lost opportunity to understand base interpretation skills and relevant data. Furthermore, despite the additional training, all but two studies excluded common STEMI mimics such as Left Bundle Branch Blocks and pacemakers within their results (Davis et al., 2007; Mencl et al., 2013). This could be interpreted as influencing the data by removing a level of complexity compared to real-world interpretation and fails to help answer the question of ambulance officer autonomous diagnostic accuracy for accurate research (Ducas et al., 2012; Feldman et al., 2005; Le May et al., 2006b; Trivedi et al., 2009).

One possible explanation for reduced specificity (67%) found by Ducas et al. (2012) could be the educational background and training of the ambulance officer. Ambulance services have a variety of educational models that may include basic in-house training or tertiary/high levels of education. Internationally, the level of education and training within an ambulance service is defined as being aligned to either an Anglo-American or Franco-German philosophy. The Anglo-American philosophy advocates a ‘scoop and run’ model that aims to rapidly transport patients to the hospital with intervention provided en-route by ambulance officers. In contrast, the Franco-German model is based on a philosophy of ‘stay and stabilise’. The later model is aimed toward bringing the hospital to the patient and is usually crewed by doctors with an extensive scope of practice and advanced equipment (Al-Shaqsi, 2010). The literature review material sits within the context of the Anglo-American model. Consistent with this, this thesis and the model found within New Zealand lends itself toward the Anglo-American model and offers a similar level of ambulance officer education.

Within New Zealand, practice level is an unvalidated proxy for 12-lead ECG education. It is however entirely possible for a university graduate with tertiary level 12-lead ECG education to be employed at a basic practice level. Conversely, an ambulance officer with intermediate or advanced practice level may not have completed formal 12-lead ECG education. The variety and differences of practice level were not investigated by

any of the authors within the literature review. The studies reviewed all relate to the advanced practice level and report no comparison with intermediate or basic practice level (Ducas et al., 2012; Le May et al., 2006b). Therefore, this review may be skewed toward reporting results for ambulance officers with wider experienced/education or advanced practice level.

2.9 Chapter Summary

This chapter reports the results of a literature review examining whether ambulance officers can correctly identify STEMI by reviewing a 12-lead ECG. The review identifies a paucity of current literature and highlights potential bias due to the practice level and additional training provided by the authors. There are conflicting and inconsistent results with regard to sensitivity and specificity. This promotes uncertainty and does not help determine the ambulance officers' true ability to diagnose STEMI. The benefit of clarifying this information is to inform a system for improved patient outcome and has the potential to promote early access to treatment which is associated with reduced duration of hospitalisation and decreased mortality rates.

It is important to understand the effect of real-world complexity, such as STEMI mimics, within the unadulterated setting. The removal of complexity and inclusion of focused training prior to the research restrict our ability to fully understand the real-world ability of the ambulance officer in the performance and interpretation of a 12-lead ECG.

This literature review examined and investigated the agreement between the ambulance officer and hospital in the diagnosis of STEMI. Sensitivity of the proportion of ambulance officer-recognised cases among all cases with the final STEMI diagnosis and predictors of ambulance officer and hospital STEMI diagnosis have been explored. There was variation in the reported sensitivity (from 75% to 99%) and specificity (from 53% to 97%). There were also substantial differences in the study design and methods. This review uncovered a small number of predictors to ambulance officer STEMI diagnostic accuracy. Any nuances to first medical contact retrieval location, ambulance officer practice level or clinical presentation in relation to diagnostic accuracy, however, have yet to be investigated. Studies within this review were classified based on the authors' description of the study type and the alignment of scientific evidence with patient care.

Chapter 3 METHODS

3.1 Introduction

In the previous chapter, I used a semi-structured literature review to investigate whether ambulance officers can correctly identify STEMI by reviewing a 12-lead ECG. The review identified a paucity of current literature and highlighted potential bias due to differing practice levels, exclusion of STEMI mimic and additional training.

This chapter describes the methods used to investigate the accuracy of STEMI diagnosis by ambulance officers in Auckland. The primary aim of this thesis is to investigate whether those patients with STEMI were recognised as having STEMI by ambulance officers compared with confirmed hospital diagnosis of STEMI (Confirmed final hospital diagnosis of STEMI with the requirement for treatment by PCI or thrombolytic therapy). The secondary aim is to identify predictors of ambulance and hospital diagnostic agreement. This includes patient demographics, ambulance service operational factors and clinical management compliance.

The methods are described according to the STrengthening the Reporting of OBservational studies in Epidemiology (STROBE) guidelines (Vandenbroucke et al., 2014). There are 10 parts to the STROBE methodology that will be described: study design, setting, participants, variables, data sources, bias, study size, missing data, quantitative variables and statistical methods. These guidelines were used to increase precision and thoroughness in the reporting of studies.

3.2 Study Design

This study used a cross-sectional observational design to investigate prehospital STEMI diagnostic accuracy, with emphasis on the Auckland ambulance officer. This was achieved through a review of ambulance officer historical electronic patient report form (ePRF) data and hospital final diagnosis data. The retrospective approach allowed for ambulance officer diagnosis without focused education or training. The data were analysed to compare if the ambulance officer working diagnosis (clinical impression of acute coronary syndrome and 12-lead ECG STEMI interpretation) matched hospital final diagnosis.

3.3 Setting

Auckland is New Zealand's largest city and its most populous region with an estimated 1.57 million people (Statistics New Zealand, 2017). There are four main hospitals within the wider Auckland geographic region which for the remainder of the study will be de-identified and anonymised using the following abbreviated terms HOSP 1, HOSP 2, HOSP 3 and HOSP 4. These hospitals are serviced by St John, which covers 97% of New Zealand's geographic area and is the only emergency ambulance service provider within the Auckland region. St John ambulance service nationally has more than 1,600 professional paid staff and over 3,000 volunteer officers. Annually, St John attends more than 400,000 emergency calls and dispatches an ambulance to 1,300 emergency calls daily (Dicker, Howie & Tunnage, 2017). Data of all patients with STEMI in the Auckland region, including those transported by emergency ambulance, is recorded via a centralised body for the purpose of clinical audit, quality improvement and the investigation of disease outcomes.

Prehospital protocol dictates that the suspected STEMI 12-lead ECG is transmitted to the nearest hospital by the ambulance officer. The 12-lead ECG is interpreted by a doctor and if there is STEMI agreement, arrangements are made to coordinate local reperfusion therapy or bypass to an alternate hospital with available reperfusion facilities. Prior to arrival, the ambulance officer will contact the hospital via a Very High Frequency (VHF) radio to confirm acceptance or bypass of the hospital.

This study was conducted within the Auckland division of St John ambulance service and the four regional Auckland public hospitals. All patients within the Auckland region who had a confirmed hospital diagnosis of STEMI had their diagnosis recorded at the time of presentation via the centralised registry. The Northern Regional Alliance collates hospital STEMI data as part of the Northern Regional District Health Board implementation of Government health policy. This data is subsequently entered into a national Catheter Lab/PCI registry and is linked with the acute coronary syndrome registry to help form the New Zealand Acute Coronary Syndromes Quality Improvement (ANZACS QI) database.

3.4 Participants

The participants were hospital patients (cases) within the Auckland region diagnosed with STEMI and recorded within the Northern Regional Alliance and St John database.

Data was collected for the period between the 1st April 2016 to 30th June 2016. The diagnostic criteria for inclusion were cases suspected by the ambulance officers to be a STEMI / acute coronary syndrome or those diagnosed in hospital as a STEMI and recorded in the Northern Regional Alliance register.

The analysis within this thesis included all cases that were transported by ambulance for whom a cardiac clinical impression term of acute coronary syndrome (Table 8) and/or ECG described as STEMI was recorded. To add certainty to a positive diagnosis of STEMI by an ambulance officer, the criteria were refined to a sub-set of the total population that met the following criteria: both a cardiac clinical impression term relating to acute coronary syndrome (Table 8) and an ECG described as STEMI (*Figure 1*).

Table 8 ePRF *Cardiac Clinical Impression Terms relating to Acute Coronary Syndrome*

ePRF Cardiac clinical impression terms
• Acute myocardial infarction of anterior wall
• Acute myocardial infarction of anterolateral wall
• Acute myocardial infarction of inferior wall
• Acute myocardial infarction of inferolateral wall
• Acute myocardial infarction of infero-posterior wall
• Acute myocardial infarction of septum
• Acute ST-segment elevation myocardial infarction
• Cardiac chest pain
• Myocardial ischaemia

The inclusion criteria for hospital cases is the confirmed diagnosis of STEMI by a cardiologist and the requirement for treatment by PCI or thrombolytic therapy. There were four hospital exclusion criteria. Firstly, cases where reperfusion therapy was contraindicated were not reported within the data provided. Secondly, STEMI cases transported from outside of the Auckland region were deemed ineligible due to the nature and locality of this study. Thirdly, hospital cases with no match to St John ePRF data. Finally, cases where cardiac arrest occurred were excluded due to the complex nature and emergent treatment requirements placed on the ambulance service and hospital. All patients meeting the criteria were included in this study irrespective of age, sex, or treatment.

3.5 Variables

The clinical impression terms used in the analysis allowed for variables associated with STEMI or acute coronary syndrome, Table 8. When the clinical impression term was accompanied by a 12-lead ECG diagnosis, it provided confidence in the intent of the ambulance officers overall diagnosis. The primary outcome measures were sensitivity, specificity, PPV and NPV. Secondary outcomes diagnostic predictors were calculated by adjusted odds ratio analysis.

Hospital diagnosis was seen as the 'gold standard' when determining a diagnosis of STEMI. Each patient included in the hospital data had a confirmed cardiologist diagnosis of STEMI and the requirement for treatment by PCI or thrombolytic therapy. This offers little doubt that STEMI took place and was used as the variable that the ambulance officer diagnosis is measured against.

Key patient information from the ambulance ePRF data fields was collected and recorded onto a structured form: Appendix G. The data were grouped into three main fields (demographics, operational and clinical). Patient demographic characteristics included age in years, sex and ethnicity as described and recorded by the ambulance officer (Table 9). Both age and date of birth are recorded on the ePRF. Age was calculated as the difference between the incident date and the date of birth and was cross-checked with the age recorded on the ePRF. In cases where the two age values were not equal, age was checked with the hospital data. Sex was treated as a binary variable and based on the ambulance officer recording. The ethnic grouping was taken from the ePRF and limited by the option fields within the St John ePRF system. These option fields are consistent with New Zealand census categories and deemed appropriate given the small number of cases within this study.

Ambulance operational variables were measured and are outlined in Table 9. The variable grouping for incident retrieval location is determined on one of three compulsory ePRF field options: Home, Public (place) and Healthcare referral. This allows the ambulance officer the ability to record where the ambulance made first contact with the patient. For the incident retrieval location determinate to be classified as 'healthcare referral', a registered healthcare professional had requested the ambulance to attend the incident location. This is usually as a result of a patient evaluation by that healthcare professional. Information regarding the type of healthcare

facility is not a compulsory element and can relate to several medical incident locations: General practitioners office, hospital, residential care facility or dentist.

Table 9 *St John Data Fields*

St John Data fields
• **Demographic** Sex, Age (DOB), Ethnicity • **Operational** Incident retrieval location, practice level, Scene time (minutes), hospital name and arrival time • **Clinical** Patient clinical impression variables Treatment/intervention variables ECG interpretation (STEMI Type variables)

Note. DOB = Date of birth; ECG = Electrocardiogram; STEMI = ST-elevation myocardial infarction

The time interval at scene was calculated as the difference between ambulance arrival and departure times. To confirm the information the ePRF performs an automatic calculation of scene time as part of the data set. Ambulance officer practice level, final hospital destination and arrival time characteristics are automated fields provided within the ePRF system. The practice level is consistent with the New Zealand ambulance service structure (Table 1). The hospital name is recorded and utilised within the inclusion criteria. Confirmation of hospital destination was cross-checked with the Northern Regional Alliance data by reviewing patient characteristics such as age, sex, and arrival time at the hospital to confirm a case match.

Variables of patient presentation within the ePRF were appraised to investigate diagnosis. These included key information such as chest pain and descriptive terms associated with acute coronary syndrome and STEMI type. Chest pain severity is often assessed using a scale from ‘0 to 10’ (10 being the highest level of pain) (Wong & Baker, 2001). This allows an understanding of the patients (subjective) level of pain. Due to the complexity of objective/subjective interpretation of a pain scale, chest pain was simplified and treated as a binary variable based on ambulance officer assessment of the patient.

Cardiac clinical impression terms descriptive of acute coronary syndrome are listed within the ePRF system and allow the ambulance officer to describe the symptoms within a pre-defined field (Table 8). The ECG interpretation fields are determined by St

John as being consistent with a variety of STEMI types and are based on the location of myocardial damage. To diagnose STEMI by 12-lead ECG, the ambulance officer needs to meet the ambulance service STEMI criteria (Figure 1). Clinical impression terms describing acute coronary syndrome and ECG interpretation were investigated by reviewing ePRF clinical notes.

Additional key clinical determinants were the status code (objective patient symptom severity) and treatment consistent with the ILCOR guidelines for STEMI. The status code variable is the ambulance officer's impression of patient severity and threat to life. This is recorded on a scale within the ePRF with Status One representing an 'immediate threat to life' to Status Four, 'no threat to life': Table 10. Patient status variables relate to the initial clinical impression of severity at first contact.

Table 10 *Ambulance Status Codes*

Status[a]	**Threat to life**
One	Immediate
Two	potential
Three	unlikely
Four	None
Zero	Dead

Note. [a] Ambulance clinical status is a numerical estimate of the patient's clinical condition at first contact. This is subjective and requires clinical judgement.

Clinical treatment by the ambulance officer consisted of morphine analgesia: glyceryl trinitrate (GTN): intravenous catheter placement (IV) and acetylsalicylic acid (aspirin) (Leman & Morley, 2016). Each treatment was recorded as a binary value to establish if provided or not. Finally, data relating to cardiac arrest exclusion criteria inherent within the study design was recorded. Hospital variables of STEMI type, reperfusion management and final hospital destination were used to provide a comparison of findings, Table 11. This information was provided within predefined fields.

Table 11 *Hospital Data Fields*

Recorded Data fields	
• Hospital name	HOSP 1, HOSP 2, HOSP 3, HOSP 4
• STEMI Type	Anterior, Other, LBBB
• Acute management type	PCI, Thrombolysis or None.
• Hospital arrival method and time	Self-presented or Ambulance

Note. LBBB = Left bundle branch block; STEMI = ST-elevation myocardial infarction: PCI = percutaneous coronary intervention: HOSP = Hospital.

3.6 STEMI Data Source

Data were obtained from two sources. First, hospital variables for patients with STEMI originate from the four Auckland hospitals. The Northern Regional Alliance collates and summarises a range of clinical, demographic, social and health-related measures. The data within the Northern Regional Alliance database is transcribed from the hospital medical records. Following arrival at an Auckland hospital, those with acute coronary syndrome symptoms are investigated for STEMI and the diagnostic and demographic details are recorded onto the hospital medical records (Table 11). Data collection for the hospital confirmed STEMI variables are subsequently collated and securely held by Northern Regional Alliance. No additional data was provided by Northern Regional Alliance on those patients contraindicated to STEMI management or those with no diagnosis of STEMI.

Second, variables measuring the ambulance officer patient care were abstracted from the St John ambulance ePRF system with the assistance of a St John Clinical Research Fellow. Source information for each variable is shown in Appendix F.

Ambulance officers are required to input their findings, treatment, and a photograph of the patient's 12-lead ECG into an ePRF tablet (Samsung android tablet and Valencia Technologies, CareMonX ePRF software). St John ambulance patient STEMI data is captured at the time of patient contact within the ambulance vehicle via the ePRF system along with several data field measures, (Table 9). This includes interpretation of STEMI, via a prehospital 12-lead ECG acquired by the ambulance officer using the

LIFEPAK 12 or LIFEPAK 15 (both manufactured by Medtronic Physio-Control, Redmond, WA). The clinical impression of acute coronary syndrome and 12-lead ECG interpretation were both recorded by the ambulance officer on the ePRF at the time of patient contact in addition to interventions and treatment. This information was subsequently transcribed onto a form: Appendix G.

All ambulance data automatically uploads to the ambulance service secure database on completion of patient contact. St John ambulance further records operational performance times via the ePRF system. St John ambulance collates this information for administrative use, account generation and clinical audit. This data is then archived in a secure database.

Matching of ambulance ePRF data and hospital data used five patient identifiers common to both data sets. These were: Patient age, sex, date, hospital, and hospital arrival time. Any discrepancies in the match were investigated by reviewing the ambulance service original ePRF data file to confirm details. The patient name was encoded within the ambulance data and was therefore not utilised. Each matched case was assigned a unique identification number and entered into a secure excel spreadsheet file (Microsoft, Redmond, WA, USA) by the author of this thesis.

3.7 Potential Bias

In this thesis, patients were excluded if they were transported from outside of the Auckland region or if they had a cardiac arrest. Case selection was centred on factors as outlined above (3.4), and it is acknowledged that case exclusion has the potential to prejudice the data (Pannucci & Wilkins, 2010).

It is highly likely that those cases transported and referred to an Auckland hospital from outside of the study area will have had a prior healthcare assessment, investigation, and diagnosis. It is possible, however, that there was selection bias by excluding those who were transported from outside of the Auckland region. It is a possibility that it was the ambulance officer who made the initial diagnosis of STEMI with the patient subsequently referred by a doctor to the Auckland region for treatment. It is important to retain the ability to investigate ambulance officer autonomous clinical decision making in regard to diagnosis. Due to the uncertainty and the potential of prior information that may influence ambulance officer diagnosis, it is reasonable to exclude this data given the intent and locality of this thesis.

It is recognised that there is an increased risk of cardiac arrest for those with STEMI (Rab et al., 2015). However, in cardiac arrest, the priority is on resuscitating the patient rather than interpreting the pre-arrest ECG. Prehospital cardiac arrest is a complex and intense event that requires immediate action by following a cardiopulmonary resuscitation algorithm. This is a series of interventions that include cardiopulmonary resuscitation, defibrillation, and pharmacological intervention (Halperin et al., 2016). The skills and actions required are focused on quality resuscitation rather than obtaining a 12-lead ECG. Whilst it is possible that prior to or following resuscitation a diagnosis of STEMI is made, it is unrealistic to expect this to happen given the complex circumstances. To avert bias when producing the database and data sets, quality checks and a strict process was followed. These are described in detail with the results reported in section 4.3.

3.8 Study Size

The study sample size was informed by the previous work of Cheskes et al. (2011). They investigated paramedic STEMI diagnosis and hospital bypass in a sample of 175 patients. Cheskes et al. (2011) used *a priori* power analysis to calculate study size. The investigators assumed a sensitivity of 70% and a measure of accuracy of +/-10%. In addition, the calculation assumed statistical significance of $\alpha = 0.05$ whilst denoting a confidence interval of 95%. The study size is consistent with that of New Zealand ambulance officer STEMI research that involved 60 patients (Davis, 2018). The current thesis determined size by the number of identified STEMI cases recorded in the Auckland region during the three-month observation period. This included 268 STEMI cases that met the study eligibility criteria, with 138 from the total population group being excluded.

3.9 Missing Data

It is not mandatory for the ambulance officer to record patient pain severity within the ePRF. Therefore, ePRF data were missing for a number of ‘initial chest pain’ and ‘final chest pain’ variables. Initial and final chest pain is a ‘yes/no’ value within the ePRF and for this thesis a strategy for an absent binary response resulted in a ‘no’ (Gearing, Mian, Barber, & Ickowicz, 2006).

3.10 Quantitative Variables

Patient characteristics, operational and clinical variables are all reported without modification from the original data set provided by St John ambulance and the Hospital.

All additional continuous variable remained ungrouped to allow for retention of all information. Groups and variable chosen are reported without change to the original data set, so as to not affect modifiers or confounders. Factors that may influence diagnosis rather than as a result of diagnosis were included in the adjusted odds ratio analysis.

3.11 Statistical Methods

Data from both St John ambulance and hospital records were exported to an Excel spreadsheet (Microsoft, Redmond, WA, USA) and analysed using Statistical Package for Social Science (SPSS) version 23.0 software (IBM SPSS Statistics for Apple, Armonk, NY: IBM Corp).

Data were screened to ensure no data entry errors or outliers occurred with corrections made prior to analysis. Sensitivity, Specificity, NPV and PPV were calculated. Distribution was investigated and was found not to be normal. Therefore, non-parametric techniques were used.

Violation of assumptions was tested followed by distribution bivariate analysis utilising Pearson Chi-square test for categorical data. Cramer's V and *Phi* were used to calculate effect size.

There is no formal way to test multicollinearity within IBM SPSS, therefore collinearity statistics were utilised to ensure tolerance values did not indicate high correlation by showing a value less than 0.1 (Pallant, 2013).

Bivariate regression analysis of characteristics of included cases was performed to identify the unadjusted odds ratio (UOR) for variables significant at the $p < 0.05$ level. Assumptions for sample size were reviewed via the descriptive statistics looking for categorical predictors with limited cases.

The data were subsequently analysed using a forced entry model to identify predictors of ambulance and hospital diagnostic agreement (AOR). The Omnibus Tests of Model Coefficients provided details on 'goodness of fit' test for the model and showed

significance (p = .000). Hosmer and Lemeshow test further support the model with a value greater than .05 (p = .580). The model summary provided information on the usefulness of the model by reviewing Cox & Snell R Square and Nagelkerke R Square values.

3.11.1 Comparator definitions

Total cohort (total-cohort): All patients in the study that met inclusion criteria and were transferred to hospital by ambulance and had a matched hospital record. The diagnostic criteria for inclusion were either those cases suspected by ambulance officers to be an acute coronary syndrome or cases diagnosed and treated in hospital for STEMI.

Hospital STEMI positive (hospital-positive): The final diagnosis of STEMI as determined by a cardiologist was used as the gold standard for comparison. These patients had hospital confirmation of STEMI and the requirement for treatment by PCI or thrombolytic therapy.

Hospital STEMI negative (hospital-negative): The final diagnosis of no-STEMI as determined by a cardiologist. These patients had hospital confirmation of no-STEMI or were contraindicated to PCI or thrombolytic treatments.

Ambulance STEMI positive (ambulance-positive): Patients who had both a reported cardiac clinical impression of acute coronary syndrome (Section 3.4) and a 12-lead ECG interpretation of STEMI as determined by the ambulance officer.

Ambulance STEMI negative (ambulance-negative): Patients who had one, but not both diagnostic criteria of either a cardiac clinical impression of acute coronary syndrome (Section 3.4) or a 12-lead ECG interpretation of STEMI as determined by the ambulance officer.

3.11.2 Sensitivity

Sensitivity is a measure of the validity of a screening test (Hennekens & Buring, 1987). It is defined as the proportion of True Positive cases amongst all True Positive and False Negative cases (Figure 4). In the current study, sensitivity is used to measure the ability of ambulance officers to correctly identify patients with STEMI. Here, it is defined as the proportion of ambulance positive patients amongst all hospital-positive

		Hospital Diagnosis		
		Hospital Positive	**Hospital Negative**	
Ambulance Officer Working Diagnosis	**Ambulance positive**	True Positive (TP)	False Positive (FP)	Positive Predictive Value (PPV) = TP/(TP+FP)
	Ambulance negative	False Negative (FN)	True Negative (TN)	Negative Predictive Value (NPV) = TN/(TN+FN)
		Sensitivity = TP/(TP+FN)	Specificity = TN/(TN+FP)	

Figure 4 Calculating the validity of ambulance officer STEMI diagnosis

3.11.3 Specificity

The validity of the test is defined as the proportion of True Negative cases among all True Negative and False Positive cases (Hennekens & Buring, 1987). Here, specificity is used to measure the ability of ambulance officers to correctly identify patients with no-STEMI (Figure 4). In this thesis, specificity is defined as the proportion of ambulance negative patients among all hospital-negative cases.

3.11.4 Positive Predictive Value

Positive Predictive Value (PPV) describes the probability of a patient having a STEMI if an ambulance officer has given a diagnosis of STEMI.

This is calculated by: Positive Predictive Value (PPV) = TP/(TP+FP)

3.11.5 Negative Predictive Value

Negative Predictive Value (NPV) describes the probability of a patient not-having a STEMI if an ambulance officer has given a diagnosis of no-STEMI.

This is calculated by: Negative Predictive Value (NPV) = TN/(TN+FN)

3.11.6 Predictors of Ambulance Officer Diagnosis

The following two groups were compared, Diagnostic Agreement (True Positive + True Negative) versus Diagnostic Non-agreement (False Positive + False Negative) to identify factors predictive of overall diagnostic agreement between the hospital and ambulance officer.

The analysis compared the demographic, operational and clinical variables between those with Diagnostic Agreement versus those with Diagnostic Non-agreement utilising Pearson Chi-squared test for categorical data. Cramer's V and *Phi* were used to calculate effect size using Cohen's criteria (Pallant, 2013). Unadjusted and adjusted logistic regression according to (diagnostic agreement, diagnostic non-agreement) was conducted to determine the relationship between variables and diagnostic agreement. A *p*-value of < 0.05 was considered significant.

Chapter 4 RESULTS

4.1 Introduction

In the previous chapter, I presented the methods and materials used in this study. This included a description of the research protocol and statistical methods used.

Utilising the STROBE guideline, this chapter will report the results of the data analysis in relation to the aims of this thesis. The results will show whether patients with a confirmed hospital diagnosis of STEMI were recognised as having STEMI by ambulance officers. The secondary aim results will identify predictors of ambulance and hospital diagnostic agreement. This will include patient demographics, ambulance service operational factors and clinical management compliance.

Presented first are the key characteristics and descriptive data, followed by the analysis of sensitivity, specificity, PPV, NPV and diagnostic agreement. Finally, associations between predictor variables and diagnostic agreement will be identified from a logistical regression analysis.

4.2 Participants

During the three-month study period between 1st April 2016 and 30th June 2016, 457 actual or suspected STEMI cases were identified from ambulance (n=334) and hospital (n=123) records within the study region. Of the 334 ambulance cases, 268 (80.2%) met the study criteria. Within the 123 recorded hospital cases, 51 (41.5%) met the study criteria and were included in the final analysis (*Figure* 5).

Among the 334 identified ambulance cases, 66 (19.8%) were excluded from the study. Thirty-two cases (9.6%) were excluded as the patient had a cardiac arrest. Twenty-nine cases (8.7%) were excluded due to missing or incomplete data for matching and a further five cases (1.5%) because they were transferred from outside the study region. The remaining 268 cases of ambulance-transported cases were included in the analysis.

Of the 123 cases identified from hospital records, 72 (58.5%) were excluded for one of three reasons. Firstly, 38 cases (30.9%) self-presented to hospital. Secondly, 23 (18.7%) were unable to be matched with ambulance data. Finally, 11 cases (8.9%) had a cardiac arrest. Therefore, 51 cases identified from hospital records were included in the study.

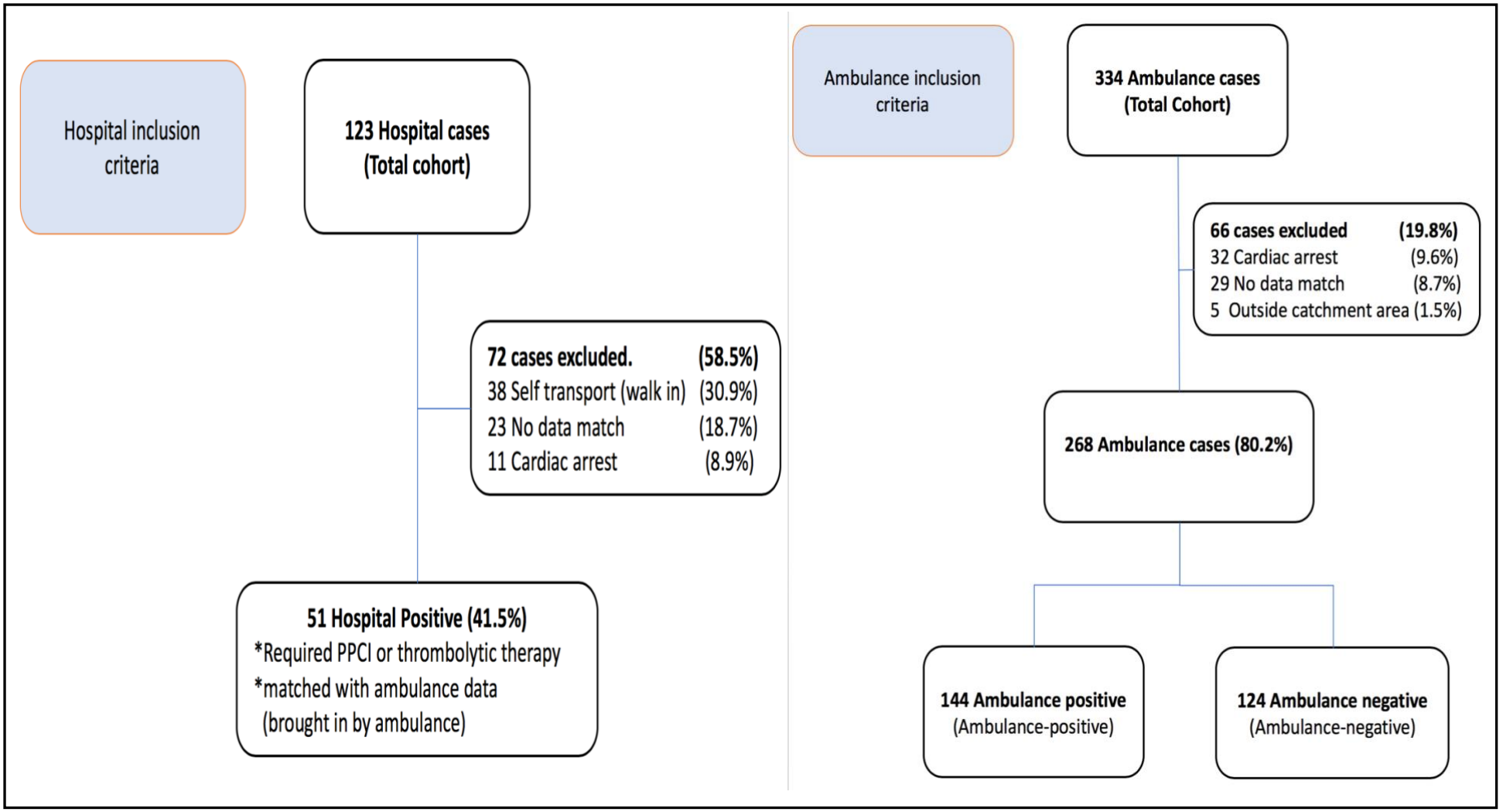


Figure 5 Flowcharts Identifying Study Participants

4.3 Descriptive Data

The characteristics of the 268 included ambulance patients are summarised in Table 12. Demographic data were available for all 268 cases described in section 4.2. The total case results show men accounted for the majority (61.6%) of the sample. Males were younger than the females, with a median age of 65 years (IQR: 53 to 78) versus the females, 74 years (IQR: 65 to 86). The overall mean age was 67 years (SD: 17.7: not shown) with a median of 69 years and a range of 55 to 86 years. The age distribution was therefore left-skewed. When applying the ethnicity classification protocol of the New Zealand Ministry of Health the majority of patients identified as New Zealand European (61.2%), (Ministry of Health, 2004).

With the exception of HOSP 3 (<10% of the total-cohort), operational characteristics show that the proportion of patients transported to each destination was evenly distributed (Table 12). The home retrieval location represented 65.3% of the cases and those transported from a healthcare location were 22.8%. The highest ambulance officer practice level was intensive care paramedic with 54.9% of cases. The median time the ambulance officer remained on the scene was 21 minutes with a range of 15 to 28 minutes.

The clinical characteristics for diagnosis recorded by the ambulance officer are presented in Table 12. Patient status represents ambulance officer assessed symptom severity at first contact, with 93.7% of patients being status ‘One to Three’. The ambulance officer recorded that 49.3% of all cases presented with chest pain when first examined. The proportion of patients with chest pain reduced to 43.3% of all patients at the final evaluation. Of the 268 patients, most did not receive morphine (78.7%) or GTN (72.4%). Both aspirin administration (47.4%) and IV placement (49.6%) were provided for almost half of all the cases. The suspected STEMI type by coronary vessel was available for the majority of the 268 ambulance cases (98.5%). Septal STEMI was the most common cardiac clinical impression (47.8%), whereas Posterior STEMI was the least common (2.6%).

Table 12 *Characteristics of Included Cases*

Characteristics	**Total Cases**		**Amb Negative Hosp Positive**		**Amb Positive Hosp Negative**		**Amb Negative Hosp Negative**		**Amb Positive Hosp Positive**	
	***n*=268**	**%**	***n*=8**	**%**	***n*=101**	**%**	***n*=116**	**%**	***n*=43**	**%**
Demographic										
Sex										
Female	103	38.4%	4	50.0%	35	34.7%	53	45.7%	11	25.6%
Male	165	61.6%	4	50.0%	66	65.3%	63	54.3%	32	74.4%
Age (years)										
Male: Median [IQR]	65 [53 to 78]		67 [61 to 70]		63 [54 to 73]		73 [56 to 83]		59 [52 to 71]	
Female: Median [IQR]	74 [65 to 86]		52 [42 to 66]		74 [67 to 86]		75 [63 to 86]		69 [67 to 81]	
Ethnicity										
NZ European	164	61.2%	2	25.0%	53	52.5%	80	69.0%	28	65.1%
Māori	9	3.6%	1	12.5%	4	4.0%	3	2.6	1	2.3%
Asian	35	13.0%	4	50.0%	16	15.8%	11	9.5%	4	9.3%
Pacific peoples	28	10.4%	1	12.5%	13	12.9%	11	9.5%	3	7.0%
Other	32	11.9%	0	0.0%	14	13.9%	11	9.5%	7	16.3%

Characteristics	Total Cases		Amb Negative Hosp Positive		Amb Positive Hosp Negative		Amb Negative Hosp Negative		Amb Positive Hosp Positive	
	***n*=268**	**%**	***n*=8**	**%**	***n*=101**	**%**	***n*=116**	**%**	***n*=43**	**%**
Operational										
Destination hospital										
HOSP 1	75	28.0%	2	25.0%	23	22.8%	37	31.9%	13	30.2%
HOSP 2	73	27.2%	2	25.0%	28	27.8%	36	31.0%	7	16.3%
HOSP 3	23	8.6%	0	0.0%	11	10.9%	11	9.5%	1	2.3%
HOSP 4	97	36.2%	4	50.0%	39	38.6%	32	27.6%	22	51.2%
Incident retrieval location										
Home	175	65.3%	8	100%	56	55.4%	84	72.4%	27	62.8%
Public	32	11.9%	0	0.0%	8	7.9%	16	13.8%	8	18.6%
Healthcare referral	61	22.8%	0	0.0%	37	36.6%	16	13.8%	8	18.6%
Ambulance officer level of practice										
ICP	147	54.9%	7	87.5%	60	59.4%	47	40.5%	33	76.7%
PARA	105	39.2%	1	12.5%	36	35.7%	58	50.0%	10	23.3%
EMT	16	6.0%	0	0.0%	5	5.0%	11	9.5%	0	0.0%
Median scene time. **(**Minutes) [IQR]	21 [15 to 28]		16 [11 to 20]		21[15 to 28]		25 [17 to 34]		19 [15 to 22]	

Characteristics	Total Cases		Amb Negative Hosp Positive		Amb Positive Hosp Negative		Amb Negative Hosp Negative		Amb Positive Hosp Positive	
	n=268	%	*n*=8	%	*n*=101	%	*n*=116	%	*n*=43	%
Clinical										
Initial clinical status										
One	73	27.2%	1	12.5%	28	27.7%	8	6.9%	36	83.7%
Two	101	37.7%	7	87.5%	55	54.5%	32	27.6%	7	16.3%
Three	77	28.7%	0	0.0%	16	15.8%	61	52.6%	0	0.0%
Four	17	6.3%	0	0.0%	2	2.0%	15	12.9%	0	0.0%
Initial chest pain [a]										
No	94	35.1%	3	37.5%	29	28.7%	28	24.1%	41	95.3%
Yes	132	49.3%	5	62.5%	58	57.4%	62	53.4%	0	0.0%
Final chest pain [b]										
No	37	13.8%	4	50.0%	23	22.8%	37	31.9%	35	81.4%
Yes	116	43.3%	4	50.0%	40	39.6%	13	11.2%	1	2.3%
Morphine										
No	211	78.7%	3	37.5%	81	80.2%	7	6.0%	25	58.1%
Yes	57	21.3%	5	62.5%	20	19.8%	109	94.0%	18	41.9%
Aspirin										
No	141	52.6%	2	25.0%	39	38.6%	24	20.7%	35	81.4%
Yes	127	47.4%	6	75.0%	62	61.4%	92	79.3%	8	18.6%

Characteristics	Total Cases		Amb Negative Hosp Positive		Amb Positive Hosp Negative		Amb Negative Hosp Negative		Amb Positive Hosp Positive	
	***n*=268**	**%**	***n*=8**	**%**	***n*=101**	**%**	***n*=116**	**%**	***n*=43**	**%**
GTN										
No	194	72.4%	2	25.0%	64	63.4%	9	7.8%	22	51.2%
Yes	74	27.6%	6	75.0%	37	36.6%	107	92.2%	21	48.8%
IV access										
No	133	49.6%	2	25.0%	42	41.6%	32	27.6%	38	88.4%
Yes	135	50.4%	6	75.0%	59	58.4%	84	72.4%	5	11.6%
STEMI type										
Anterior	50	18.7%	1	12.5%	20	19.8%	11	9.5%	16	37.2%
Inferior	70	26.1%	1	12.5%	36	35.6%	7	6.0%	26	60.5%
Lateral	9	3.4%	0	0.0%	4	4.0%	5	4.3%	0	0.0%
Posterior	7	2.6%	0	0.0%	1	1.0%	5	4.3%	1	2.3%
Septal	128	47.8%	0	0.0%	40	39.6%	88	75.9%	0	0.0%
No STEMI/other	4	1.5%	6	75.0%	0	0.0%	0	0.0%	0	0.0%

Note. Totals of percentages are not 100 for every characteristic and have been simplified due to rounding. IQR = inter-quartile range; ICP = Intensive care paramedic; PARA = Paramedic; EMT =emergency medical technician; GTN = glyceryl trinitrate; IV = intravenous; STEMI = ST-elevation myocardial infarction; NZ = New Zealand: HOSP = Hospital.

Missing cases: [a] n = 42 (16%), [b] n = 115 (43%)

4.4 Diagnostic Sensitivity

Overall, of the 51 hospital positive cases, 43 were ambulance positive and 8 were ambulance negative resulting in a diagnostic sensitivity of 84.3% (95% CI, 71.41 to 92.98), *Figure* 6. This represents the probability of a positive ambulance diagnosis if the hospital diagnosis is STEMI (Sensitivity = TP/(TP+FN)).

		Hospital Diagnosis		
		Hospital Positive	**Hospital Negative**	
Ambulance Officer Working Diagnosis	**Ambulance Positive**	43 (TP)	101 (FP)	Positive Predictive Value (PPV) = 43/144 = 29.9%
	Ambulance Negative	8 (FN)	116 (TN)	Negative Predictive Value (NPV) = 116/124 = 93.6%
		Sensitivity = 43/51 = 84.3%	Specificity = 116/217 = 53.5%	**TOTAL 268 cases**

Figure 6 Measurement of Ambulance Officers STEMI Diagnosis

There were eight missed STEMI cases (false-negatives) that were ambulance-negative and hospital-positive. The patient characteristics for the eight missed STEMI cases are presented in Table 12 and show all missed STEMI were transported from home (n=8), half were of Asian ethnicity (n=4) and seven out of eight were attended to by those with a practice level of intensive care paramedic. All cases omitted terms relating to a clear cardiac clinical impression of STEMI or acute coronary syndrome, with six out of eight not describing the ECG as STEMI: Table 13.

Table 13 *Ambulance False-Negative Cases*

Clinical impression terms (Total *n*=8)	ECG recorded as STEMI?
Atypical (non-cardiac) chest pain	No
Atypical (non-cardiac) chest pain	No
Atypical (non-cardiac) chest pain	No
Atypical (non-cardiac) chest pain	Yes
Acute pulmonary oedema	No
Acute pulmonary oedema	Yes
Rigours	No
Cardiac (other)	No

4.5 Diagnostic Specificity

Of the 217 hospital-negative cases, 116 were ambulance-negative and 101 were ambulance positive resulting in a diagnostic specificity of 53.5% (95% CI, 46.58 to 60.24), *Figure* 6. This represents the probability of an ambulance diagnosis of no-STEMI amongst those with a hospital diagnosis of no-STEMI, (TN/(TN+FP)).

Where the ambulance officer incorrectly diagnosed STEMI (false-positive group, n=101) most of the patients were male (n=66, 65.4%). In the majority of cases, an intensive care paramedic qualified ambulance officer was in attendance (n=60, 59.4%). Septal (n=40, 39.6%) or Inferior (n=36, 35.6%) STEMI were the most frequent false-positive diagnosis (Table 12).

4.6 Positive Predictive Values

The PPV identified the probability of a patient having a STEMI if an ambulance officer has given a diagnosis of STEMI. Of 144 patients that ambulance officers suspected of having a STEMI, 43 cases went on to be given a hospital diagnosis of STEMI. The PPV result indicates that the probability of patients that were ambulance-positive also being confirmed as hospital positive was 29.9% (95% CI, 26.13 to 33.88).

4.7 Negative Predictive Values

NPV was defined as the probability of a patient not-having a STEMI if an ambulance officer has given a diagnosis of no-STEMI. Of the 124 patients with an ambulance officer's clinical impression of no-STEMI, 116 also received a hospital diagnosis of no-

STEMI. The calculated NPV indicates that the probability ambulance-negative patients also being confirmed as hospital-negative was 93.6% (95% CI, 88.35 to 96.52).

4.8 Predictors of Ambulance Officer Diagnosis

The following two groups were compared, diagnostic Agreement (TP + TN) versus diagnostic non-agreement (FP+FN) to determine the predictive factors associated with overall diagnostic agreement between the hospital and ambulance officer. A descriptive analysis of demographic, operational and clinical factors according to diagnostic agreement was performed. Pearson's chi-square test indicated that column proportions differed between the patient incident retrieval location, scene time, initial clinical status, those with initial chest pain, aspirin, GTN, IV insertion and STEMI type (Table 14).

Table 14 *Diagnostic Agreement Variables: Pearson's Chi-Square test*

	Total	%	Diagnostic Agreement	%	Diagnostic Disagreement	%	Chi square test of independence	Effect Size*
	n=268		n=159		n=109			
Demographic								
Sex							$\chi_2(1) = 0.55$ $p = 0.46$	
Female	103	38.4%	64	62.1%	39	37.9%		
Male	165	61.6%	95	57.6%	70	42.4%		
Age							$\chi_2(1) = 6.3$ $p = 0.48$	
Ethnicity							$\chi_2(4) = 8.79$ $p = 0.07$	
NZ European	164	61.2%	108	65.9%	56	34.1%		
Māori	9	3.40%	4	44.4%	5	55.6%		
Asian	35	13.1%	15	42.9%	20	57.1%		
Pacific peoples	28	10.4%	14	50.0%	14	50.0%		
Other	32	11.9%	18	56.2%	14	43.8%		
Operational								
Destination hospital							$\chi_2(3) = 2.7$ $p = 0.44$	
HOSP 1	75	28.0%	50	66.7%	25	33.3%		
HOSP 2	73	27.2%	43	58.9%	30	41.1%		
HOSP 3	23	8.6%	12	52.2%	11	47.8%		
HOSP 4	97	36.2%	54	55.7%	43	44.3%		

	Total	%	Diagnostic Agreement	%	Diagnostic Disagreement	%	Chi square test of independence	Effect Size*
Incident retrieval location							χ_2 (2) = 14.6 ***p* < 0.001**	Cramer's V (-.23) = Medium
Home	175	65.3%	111	63.4%	64	36.6%		
Public	32	11.9%	24	75.0%	8	25.0%		
Healthcare	61	22.8%	24	39.3%	37	60.7%		
Ambulance officer practice level							χ_2 (2) = 3.3 *p* = 0.19	
ICP	147	54.9%	80	54.4%	67	45.6%		
PARA	105	39.2%	68	64.8%	37	35.2%		
EMT	16	6.0%	11	68.8%	5	31.2%		
Scene time (minutes)			(22)		(18)		χ_2 (1) = 15.8 ***p* = 0.003**	Cramer's V (-.24) = Medium
Clinical								
Initial clinical status							χ_2 (3) = 35.0 ***p* < 0.001**	Cramer's V (-.36) = Medium
One	73	27.2%	44	60.3%	29	39.7%		
Two	102	38.1%	40	39.2%	62	60.8%		
Three	77	28.7%	61	79.2%	16	20.8%		
Four	16	6.0%	14	87.5%	2	12.5%		
Initial chest pain[a]							χ_2 (1) = 4.2 ***p* = 0.04**	*Phi* (-.13) = Small
No	94	41.6%	62	66.0%	32	34.0%		
Yes	132	58.4%	69	52.3%	63	47.7%		

	Total	%	Diagnostic Agreement	%	Diagnostic Disagreement	%	Chi square test of independence	Effect Size*
Final chest pain[b]							χ^2 (1) = 0.6 *p* = 0.44	
No	65	41.4%	38	58.5%	23	41.5%		
Yes	92	58.6%	48	52.2%	44	47.8%		
Morphine							χ^2 (1) = 0.3 *p* = 0.58	
No	211	78.7%	127	60.2%	84	39.8%		
Yes	57	21.3%	32	56.1%	25	43.9%		
Aspirin							χ^2 (1) = 16.6 ***p* < 0.001**	*Phi* (-.24) = Small
No	141	52.6%	100	70.9%	41	29.1%		
Yes	127	47.4%	59	46.5%	68	53.5%		
GTN							χ^2 (1) = 12.9 ***p* < 0.001**	*Phi* (-.21) = Small/Medium
No	194	72.4%	128	66.0%	66	34.0%		
Yes	74	27.6%	31	41.9%	43	58.1%		
IV access							χ^2 (1) = 6.3 ***p* = 0.01**	*Phi* (-.15) = Small
No	133	49.6%	89	66.9%	44	33.1%		
Yes	135	50.4%	70	51.9%	65	48.1%		

	Total	%	Diagnostic Agreement	%	Diagnostic Disagreement	%	Chi square test of independence	Effect Size*
STEMI type							χ_2 (5) = 17.5 ***p* = 0.004**	Cramer's V (-.25) = Small/Medium
Anterior	50	18.7%	27	54.0%	23	46.0%		
Inferior	70	26.1%	33	47.1%	37	52.9%		
Lateral	9	3.4%	5	55.6%	4	44.4%		
Posterior	7	2.6%	6	85.7%	1	14.3%		
Septal	128	47.8%	88	68.8%	40	31.2%		
Not stated	4	1.5%	0	00.0%	4	100.0%		

Note. Significant *p*-values (<0.05) are shown in bold face. Totals of percentages are not 100 for every characteristic and have been simplified due to rounding. ICP = Intensive care paramedic; PARA = Paramedic; EMT =emergency medical technician; GTN = glyceryl trinitrate; IV = intravenous; STEMI = ST-elevation myocardial infarction; NZ = New Zealand; HOSP = Hospital. Missing cases: [a] n = 42 (16%), [b] n = 115 (43%).

* Effect size was determined using criteria set out by Pallant (2013).

Unadjusted bivariate regression analysis was utilised to determine system or patient factors that may be related to diagnostic agreement (Diagnostic Agreement (TP + TN) versus Diagnostic Non-agreement (FP+FN)).

Of the fifteen variables, the results indicated that there was no association with the variable of sex, age, ethnicity, destination hospital, practice level, final chest pain and morphine administration. The remainder of the variables were found to have statistical significance ($p < 0.05$). The UOR for each variable is reported below in Table 15.

Table 15 *Predictors of Ambulance and Hospital Diagnostic Agreement*: *Unadjusted Odds Ratio* (UOR)

	UOR	**95% CI**	***p* -Value**
Total (n= 268)			
Demographic			
Sex			0.46
Female *	1.00		
Male	0.82	(0.50 to 1.37)	
Age	1.00	(0.99 to 1.02)	0.48
Ethnicity			0.07
NZ European*	1.00		
Māori	0.42	(0.11 to 1.61)	
Asian	0.39	(0.19 to 0.82)	
Pacific peoples	0.52	(0.23 to 1.16)	
Other	0.67	(0.31 to 1.44)	
Operational			
Destination hospital			0.44
HOSP 1*	1.00		
HOSP 2	0.72	(0.37 to 1.40)	
HOSP 3	0.55	(0.21 to 1.41)	
HOSP 4	0.63	(0.34 to 1.17)	
Incident retrieval location			**0.001**
Home *	1.00		
Public	1.73	(0.73 to 4.08)	
Healthcare referral	0.37	(0.21 to 0.68)	

	UOR	95% CI	*p* -Value
Ambulance officer practice level			0.19
ICP*	1.00		
PARA	1.54	(0.92 to 2.58)	
EMT	1.84	(0.61 to 5.57)	
Scene time (minutes)	1.03	(1.01 to 1.05)	**0.003**
Clinical			
Initial clinical status			**<0.0001**
One *	1.00		
Two	0.43	(0.23 to 0.79)	
Three	2.52	(1.22 to 5.18)	
Four	4.61	(0.98 to 21.8)	
Initial chest pain			**0.04**
No *	1.00		
Yes	0.57	(0.33 to 0.98)	
Final chest pain			0.44
No *	1.00		
Yes	0.78	(0.41 to 1.47)	
Morphine given			0.58
No *	1.00		
Yes	0.85	(0.47 to 1.52)	
Aspirin given			**<0.0001**
No *	1.00		
Yes	0.36	(0.22 to 0.59)	
GTN given			**<0.0001**
No *	1.00		
Yes	0.37	(0.22 to 0.64)	
IV access			**0.01**
No *	1.00		
Yes	0.53	(0.33 to 0.87)	

	UOR	95% CI	*p* -Value
STEMI type			**0.004**
Anterior *	1.00		
Inferior	0.76	(0.37 to 1.57)	
Lateral	1.07	(0.26 to 4.43)	
Posterior	5.11	(0.57 to 45.62)	
Septal	1.87	(0.96 to 3.66)	
Not stated	0.00	0.00	

Note. Significant *p*-values (p<0.05) are shown in boldface. ICP = Intensive care paramedic; PARA = Paramedic; EMT =emergency medical technician; GTN = glyceryl trinitrate; IV = intravenous; STEMI = ST-elevation myocardial infarction; NZ = New Zealand; HOSP = Hospital. ***** = Reference variable.

4.9 Adjustment for confounding

Binary logistic regression analysis was used to adjust for confounding. Eight significant variables associated with the diagnostic agreement were identified from the UOR analysis: Incident retrieval location, time on scene, initial clinical status, initial chest pain, aspirin, GTN, IV and STEMI type (Table 15). To determine factors that influence diagnostic agreement between ambulance and hospital, nine variables were entered into a Forced entry logistic regression model (Table 16). Results indicated two of the variables made a significant contribution to the model: Incident retrieval location of the patient, and Clinical Status. A significance level of $p < 0.05$ level was used to reject the null hypothesis. The Forced entry model, Adjusted Odds Ratio (AOR) and 95% confidence interval are presented in Table 16.

Table 16 *Predictors of Ambulance and Hospital Diagnostic Agreement: Forced Entry Model* (AOR).

	AOR	**95% CI**	***p* -Value**
Total (n= 268)			
Demographic			
Sex			0.97
Female*	1.00		
Male	0.99	(0.42 to 2.30)	
Age	0.98	(0.95 to 1.01)	0.16
Ethnicity			0.22
NZ European*	1.00		
Māori	0.94	(0.08 to 11.30)	
Asian	0.31	(0.09 to 0.98)	
Pacific peoples	0.32	(0.08 to 1.29)	
Other	0.51	(0.15 to 1.78)	
Operational			
Incident retrieval location			**0.02**
Home *	1.00		
Public	2.69	(0.72 to 9.96)	
Healthcare referral	0.36	(0.14 to 0.94)	
Ambulance officer practice level			0.14
ICP*	1.00		
PARA	2.40	(0.97 to 5.94)	
EMT	0.80	(0.12 to 5.23)	
Scene time (minutes)	1.01	(0.99 to 1.04)	0.41

	AOR	95% CI	*p* -Value
Clinical			
Status			**<0.0001**
One*	1.00		
Two	0.13	(0.05 to 0.36)	
Three	0.59	(0.17 to 2.05)	
Four	1.87	(0.18 to 19.45)	
Initial chest pain[a]			0.16
No*	1.00		
Yes	0.36	(0.09 to 1.49)	
Final chest pain[b]			0.52
No*	1.00		
Yes	1.60	(0.38 to 6.76)	

Note. Significant *p*-values (p<0.05) are shown in boldface. ICP = Intensive care paramedic; PARA = Paramedic; EMT =emergency medical technician. ***** = Reference variable.

Within the demographic variables, factors such as sex, ethnicity and age showed no statistically significant relationship to a correct diagnosis by the Ambulance officer. Whilst not showing an overall significance for ethnicity, significance was found within a subgroup. Here, those of Asian ethnicity were three times more likely when compared to a New Zealand European to have an incorrect diagnosis (AOR 0.31, 95% CI, 0.09 to 0.98, $p = 0.0$).

Out of the operational variables investigated, a significant association to patient locality and the accuracy of ambulance officer diagnosis was found. The strongest predictor for ambulance officer misdiagnosis was when called to a Healthcare retrieval location. Here, those patients that were referred and transported from a healthcare facility when compared to the home, were three times more likely to be misdiagnosed: (AOR 0.36, 95% CI, 0.14 to 0.94, $p = 0.04$). Ambulance officer practice level and the time spent on the scene treating the patient were not significant.

The clinical characteristics showed that patients deemed by the ambulance officer to have an initial clinical severity of Status Two when compared to those at Status One, were less likely to have hospital diagnostic agreement (AOR 0.13, 95% CI, 0.05 to 0.36,

$p < 0.0001$). When compared to Status One patients, those who were Status Three or Four showed no statistical significance associated with the end diagnosis after adjustment for confounding. First pain and Last pain showed no significant statistical difference for ambulance officer diagnosis within the forced entry model.

Chapter 5 DISCUSSION

Chapter 4 showed the results of the data analysis utilising the STROBE guideline. Key characteristics and descriptive data were presented first, followed by the analysis of sensitivity, specificity, PPV, NPV and diagnostic agreement. Finally, associations between predictor variables and diagnostic agreement were identified from a logistical regression analysis.

This section discusses the key findings from the analysis, recognition of patients with STEMI by ambulance officers compared with confirmed hospital diagnosis, in relation to the current literature. In addition, the secondary aims of identification of predictors of ambulance and hospital diagnostic agreement are also discussed.

This chapter draws upon the work of Dr Pat Croskerry on understanding the impact of cognitive biases on diagnosis (Croskerry, 2002). Set within a STROBE framework the significance of the findings, will be discussed in four contexts. First, the sensitivity and specificity of prehospital STEMI recognition. Second, predictors associated with ambulance officer and hospital diagnostic agreement will be discussed. Third, the findings will be examined in terms of their theoretical contribution to a prehospital system of care for STEMI. Here, the balance between the potential significance for inappropriate activation of resources and more importantly, the risk and implications of missing a STEMI diagnosis will be reviewed. Finally, limitations to the study, generalisability, future research and implications for practice will be discussed.

5.1 Key results

During the study period, 268 ambulance patients met the inclusion criteria for suspected or actual STEMI. Overall, ambulance-positive diagnosis when compared to the hospital-positive diagnosis was associated with a sensitivity of 84.3% (95% CI, 71.41 to 92.98) and a specificity of 53.5% (95% CI, 46.58 to 60.24).

Adjusted logistic regression indicated that patients were more likely to have ambulance and hospital diagnostic agreement for two reasons. First, if the ambulance officer’s assessment of initial patient severity was Status One compared to Status Two and second, if the incident retrieval location of the patient was at home compared to a healthcare facility.

5.2 Diagnostic Sensitivity

This investigation demonstrated a sensitivity by the ambulance officer of 84.3%. Previous studies reporting ambulance officer recognition of STEMI have reported sensitivity ranging from 75% to 99.5% (Davis et al., 2007; Ducas et al., 2012; Feldman et al., 2005; Le May et al., 2006b; Mencl et al., 2013; Trivedi et al., 2009). In comparison to these studies, our investigation indicates a sensitivity within the middle of this range and it is comparable to these results.

The test of sensitivity for this study identified eight hospital-positive cases that were ambulance-negative. Amongst the small number of cases where the ambulance officer did not recognise STEMI, the working diagnosis did not have a cardiac clinical impression of acute coronary syndrome and/or a 12-lead ECG described as STEMI. For misdiagnosis, the clinical impression term predominantly reported by the ambulance officer in this study was that of "atypical (non-cardiac) chest pain" (n=4).

Atypical chest pain suggests an unusual presentation or the inability to confirm a cardiac event by 12-lead ECG interpretation. Findings from this study identified that half of the misdiagnosed STEMI cases were described as an atypical (non-cardiac) chest pain. This is consistent with a previous study by Ducas et al. (2012) who found 52% of STEMI negative cases were diagnosed as 'nonspecific chest pain'. This highlights the complexity of prehospital diagnosis and 12-lead ECG interpretation.

This study identified two cases that described the 12-lead ECG as STEMI but did not offer a working diagnosis of acute coronary syndrome. The working diagnosis provided were pulmonary oedema and atypical (non-cardiac) chest pain. The differing research methods within the current literature do not elucidate on a cause for false-negative diagnosis. However, it is entirely possible that in this circumstance the ambulance officer did indeed recognised STEMI but may have noted additional symptom concerns that offered greater influence when describing the final working diagnosis.

Confirmation bias may be a contributing factor to misdiagnosis. A combination of salient features of a particular presentation could result in pattern recognition (Croskerry, 2002). For example, acute pulmonary oedema and acute coronary syndromes both commonly present with shortness of breath. This can, in turn, enable an incorrect perception of diagnostic recognition and the problem being solved. The consequences of confirmation bias relate to those who participate in observational

studies such as those performed by Feldman et al. (2005), Mencl et al. (2013) and Trivedi et al. (2009).

The evaluation of the real-world patient found within this study offers many potential differential diagnoses which may have led to an incorrect diagnosis. ‘Multiple alternatives bias’ helps to generate uncertainty and conflict due to increasing levels of complexity. This finding is supported by Mencl et al. (2013) who reported reduced sensitivity when complexity was added. The bias predicts that there is a tendency to avoid uncertainty and conflict with a potential incline to accept the initial diagnostic hypothesis rather than review the many possibilities (Ringstrom & Freedman, 2006). To further complicate matters, the volume of the decisions around the choice of procedures and treatment is dense. The sheer number of decisions and complexity of presentation seen in Appendix D may have created stress and tension, which compromised the decision-maker and the end diagnosis.

In addition to ‘multiple alternatives bias’, there may be elements of anchoring bias by the ambulance officer when providing a diagnosis. Anchoring bias offers a tendency to fixate on symptoms representative of a diagnosis and result in premature closure of thinking (Croskerry, 2002). The potential is that the ambulance officer fails to adjust to the diagnosis in light of later evaluation and information. Despite providing levels of information similar to this study (12-lead ECG and evaluation of a real patient), Ducas et al. (2012) (99%) and Le May et al. (2006b) (95%) both had higher sensitivity. Although to some extent this result differs to that of Ducas et al. (2012) and Le May et al. (2006b), it should nevertheless be noted that there was a significant period of focused training provided prior to their study which may have helped to improve their performance and mitigate anchoring bias and posterior probability error.

Reliance on prior information may influence diagnostic sensitivity. An estimate of cardiac risk may be based on prior diagnosis by way of previous medical notes, test results and discharge documentation. Additional information has the potential to result in a ‘posterior probability error’ occurring and result in an incorrect diagnosis. For example, if a patient had chest pain with a prior chest pain diagnosis of gastroesophageal reflux disease, to assume the same diagnosis is a posterior probability error. This same error could be a factor for incorrect diagnosis by way of medical history suggesting the patient is high or low risk for a cardiac event. The current literature does not discuss posterior probability error, but there is a likelihood that the

focused STEMI related research by Ducas et al. (2012) and Le May et al. (2006b) may have influenced statistical sensitivity.

5.3 Diagnostic Specificity

This study investigated complex diagnosis that differed from other research by including all STEMI type and all STEMI mimic. The retrospective design of this study was constructed from actual real-world cases and offered an accurate representation of the prehospital setting. This allowed assessment of the ambulance officers' clinical decision making with exposure to all patients without multiple alternative bias being removed by the exclusion of complex STEMI presentation. Our testing methodology further enabled greater insight into determining ambulance officer diagnosis by allowing for both cardiac clinical impression of acute coronary syndrome and ECG interpretation.

The present findings demonstrate a specificity of 53.5% (95% CI, 46.58 to 60.24) by the ambulance officer. However, direct comparison due to differing experimental designs makes this difficult to determine as Le May et al. (2006b), Trivedi et al. (2009) and Feldman et al. (2005) showed high levels of specificity (96%, 85% and 97% respectively). The difference in specificity may be due to the influence of STEMI mimic exclusion. In contrast, Mencl et al. (2013) included STEMI mimic and reported a 53% specificity (95% CI, 51 to 55) which is comparable to the findings of this study: 53.5% (95% CI, 46.58 to 60.24). Whilst the setting and conduct varied between the published studies, the exclusion of STEMI mimic offers a clear contrast in specificity that may be due to the removal of comparative complexity. Whilst our research did not investigate the ECG for mimic, it is reasonable to state that there would be STEMI mimic and areas of complexity within the 101 reported false-positive cases.

A reduction in 12-lead ECG complexity promotes caution when interpreting the high specificity findings of Trivedi et al. (2009). The inclusion of all ECG within this study, offers a potential reason as to why the specificity was found to be lower than those of Trivedi et al. (2009). As part of the inclusion criteria for this study, a 12-lead ECG was gained for all 268 ambulance cases. This represents a different 12-lead ECG for each of the 268 real-world patients. The complexity is therefore high when compared to those of Trivedi et al. (2009) who used five ECGs and removed STEMI mimic. There are limitations to the usefulness of their findings as it is unrealistic to include a small number of 12-lead ECGs to represent the prehospital population. This could lead to a

failure to allow for relative distribution of STEMI, STEMI mimic and normal ECGs for the patient population.

This study reports the overdiagnosis of STEMI for a high number of patients and results in a low specificity and low PPV (29.9% (95% CI, 26.13 to 33.88)). These New Zealand findings are similar to those observed in Canada and the United States of America (Ducas et al., 2012; Mencl et al., 2013), Table 6. Therefore, ambulance officers can identify those with prehospital STEMI but there remains a high level of overestimation thought to be STEMI for ambulance officer diagnosis to be seen as truly accurate.

5.4 Positive Predictive Value

The PPV within this study was found to be 29.9%. This result contrasts with the findings of Ducas et al. (2012), Feldman et al. (2005) and Le May et al. (2006b), who reported a PPV of 60%, 96% and 82% respectively. Given that the finding of this study is markedly different, it is difficult to ascertain the reason as to why, but differences in study design may be the answer. Notwithstanding the lack of agreement, it has been demonstrated by Le May et al. (2006b) that added responsibility or complex decision making can reduce the PPV. Le May et al. (2006b) found that when the ambulance officer was asked to interpret the 12-lead ECG for STEMI, the PPV was 82% (95% CI, 71 to 90). When the data was subanalysed to include those, who would administer thrombolysis for STEMI, the PPV dropped to 73% (95% CI, 59 to 85). The current study has demonstrated that of the 144 patients that ambulance officers suspected of having a STEMI, 43 cases were STEMI. Whilst contradictory to the literature, study design and the complexity of ‘real world’ conditions, offer a plausible reason for this discordance.

Whilst undesirable, a low level of PPV is acceptable under certain circumstances. A percentage of patients incorrectly diagnosed as STEMI by the ambulance officer might be appropriate if follow-up tests are inexpensive, quickly performed and offer limited additional stress to the patient (Hennekens & Buring, 1987). The follow-up tests in this instance relate to those who are taken to hospital by ambulance. Hospital tests include additional 12-lead ECGs and blood analysis to be classified as STEMI (see section 1.5 above). This is routine and is commonly performed with little expense or risk toward those with suspected STEMI. Additional follow-up testing to confirm prehospital diagnosis whilst undesirable is relative to the potential benefits to the patient.

A low PPV may be acceptable when the condition is life-threatening or can progress quickly. However, under these circumstances, early effective treatment must not potentiate iatrogenic complications. It is reasonable to suggest that a low level of PPV and an associated over-diagnosis offers some certainty that risk is attenuated by providing a safety net for those suspected of a life-threatening issue. A low PPV will ensure only small numbers of STEMI are missed for this important condition.

5.5 Negative Predictive Value

Consistent with the findings of Ducas et al. (2012), Feldman et al. (2005) and Le May et al. (2006b) the NPV found within this study is high. The NPV indicated that 93.6% (95% CI, 88.35 to 96.52) of hospital-negative cases were correctly identified as ambulance-negative even at the lower margin of the 95% confidence interval (88.35%). This finding indicates that the ambulance officer was able to identify many of those patients with no-STEMI whilst also offering a high level of sensitivity and correctly identifying 116 out of 124 patients.

The high level of NPV found in this study implies that an incorrect diagnosis of no-STEMI was minimised. Whilst the wider literature does not offer an analysis of the NPV in relation to prehospital STEMI, it has been demonstrated in this study that NPV is high and most cases of no-STEMI were correctly identified.

5.6 Predictors of Ambulance Officer Diagnosis

The secondary aim of this thesis was to identify predictors of ambulance and hospital diagnostic agreement. The investigation included patient demographics, ambulance service operational factors and clinical management compliance. Within this thesis hospital and ambulance officer diagnosis was strongly associated with two specific themes: Patient initial severity (status) and retrieval location, Table 16. These factors have not previously been reported within the literature but offer some insight into the unique nature of prehospital STEMI diagnosis.

The association between initial clinical severity and diagnosis showed conflicting results in accuracy. Our findings revealed those patients described as Status Two compared to Status One were less likely to have hospital diagnostic agreement (AOR 0.13, 95% CI, 0.05 to 0.36, $p < 0.0001$). With both meeting the inclusion criteria representative of a diagnosis of STEMI, it is difficult to determine why there was a

difference in accuracy. This may in part be due to the strength of the 12-lead ECG findings and/or clinical symptoms having a greater association with STEMI for those at Status One. Those at Status Two may ‘err on the side of caution’ and increase the objective severity of the patient to promote, rather than decrease a diagnosis. There are several features that may influence this and it is fair to state that it is complex.

The severity of the initial chest pain may influence interpretation and diagnosis. For example, chest pain can be described by the patient within a spectrum and is often associated with a scale of ‘0 to 10’ (10 being the highest level of pain) (Wong & Baker, 2001). A score of 10 indicates the worst pain imaginable by the patient. A patient who reports a high severity score has the potential to transfer a greater element of urgency to the situation, therefore potentially increasing the severity score from a low Status (Three/Four) toward a high status (One/Two). In addition to this, value induced bias with a tendency toward increasing the worst-case scenario may develop confidence and certainty of the ambulance officer to interpret a finding of STEMI by not wanting to miss an important diagnosis.

The sex of the patient may be a factor when the ambulance officer interprets symptom. Research by Fukuoka et al. (2007) reported compared to men, women with severe chest pain did not associate this symptom to myocardial infarction (OR, 4.95, 95% CI, 2.39 to 10.25). Men with severe chest pain were approximately twice as likely as women to interpret their symptoms as cardiac in origin. This may lead to underrepresentation of symptom for women and transfer less urgency for ambulance officer diagnosis. In addition, once an early diagnosis is accepted, there can be a tendency to prematurely close any problem-solving for diagnosis. Croskerry (2002) aligns this to pattern recognition.

Cardioprotective medications may influence diagnosis and cardiac severity. These include; statins, beta-blockers, aspirin, angiotensin-converting enzyme (ACE) inhibitors, calcium channel blockers, diuretics, nitrates, coumarins, and digoxin (Feringa et al., 2006). Cardioprotective medications offer a sense of associated risk and history and would almost certainly be reviewed as important and therefore influential for the ambulance officers interpretation of severity. The ability to understand the ambulance officers interpretation of severity in relation to end diagnostic accuracy whilst found to have differing results are outside of the scope of this study. The results, however, do offer an interesting future research opportunity.

This thesis found that when compared to the home, those patients transported from a healthcare facility were three times less likely to have diagnostic agreement with the hospital (AOR 0.36, 95% CI, 0.14 to 0.94, $p = 0.04$). There is no published evidence to suggest a direct relationship between the incident retrieval location and prehospital ambulance officer STEMI diagnosis. The reduced accuracy when transporting from a healthcare facility may be linked to the perception that the referral staff have already made the correct diagnosis. The medical referral staff may include doctors and be seen as skilled and knowledgeable in the identification of STEMI. This could result in the under investigation of patient clinical presentation and/or ECG with a subsequent reliance on the referral diagnosis. This is known as diagnostic momentum (Croskerry, 2002).

Diagnostic momentum from one healthcare professional to another, without gathering adequate verification of diagnosis, offers elements of diagnostic premature closure (Croskerry, 2002). This allows an incorrect diagnosis to stay with a patient from one healthcare professional to another. The diagnosis gathers momentum to a point were those involved appear certain it is correct. This suppresses further thinking and results in the first contact clinicians thinking being adapted and unduly influence subsequent clinicians, such as the ambulance officer.

Inadvertent premature diagnostic closure is a major default of the hypothesis generation. Hypothesis is subject to adequacy, verification, falsification, and parsimony (Kassirer Kopelman & Wong, 1991). Without this, there is a perception that everything that has been done, is not only correct, but the enthusiasm for further tests and investigation will now be low. This is known as Yin-yang out (Croskerry, 2002). This can lead to a missed opportunity to investigate an alternate condition or corroborate the prior diagnosis. It is therefore possible that following the healthcare referral that further effort and investigation did not take place by the ambulance officer for the presenting complaint. The result of which may be the reliance on a weak referral diagnosis leading the ambulance officer to subsequently misdiagnose the condition.

A prior diagnosis by a healthcare professional may have been developed on ambiguous or weak information. For example, those patients who are referred from a resthome are unlikely to have had 12-lead ECG investigation. It is, however, within the referring healthcare professionals' remit to be able to suggest diagnosis and acuity. In this instance, confirmation bias may lead to the preservation of diagnosis, that was in fact,

somewhat limited by way of a sense of urgency and limited diagnostic evaluation. With the first point of care having a healthcare professional making the initial risk assessment and referral, the triage process can at times be amplified by a potential bias and cognitive dispositions due to a process of forced abbreviated assessment (Croskerry, 2002). This, in turn, may lead to the over or under assessment of acuity, severity and diagnosis based on incident location.

5.7 The Balance Between Sensitivity and Specificity

An acceptable level of sensitivity and specificity must involve a weighing of the consequences. Low specificity is not without risk and may result in erroneously classifying a person without STEMI as having the condition. An incorrect diagnosis of STEMI can be associated with overtreatment, unnecessary cost, and the prospect of iatrogenic complications (Davis et al., 2007; Ducas et al., 2012). Outcomes of this nature can be annoying and distressing for both the provider and the recipients of healthcare (Hennekens & Buring, 1987). In contrast, the consequences of low sensitivity include leaving those with STEMI undetected. An incorrect diagnosis of no-STEMI will, therefore, result in a missed opportunity to treat the condition.

The reality within a real-world setting is that there remains a tension between sensitivity and specificity. Ideally, both sensitivity and specificity should be high. Although high specificity does not fully rule out no-STEMI, high specificity gives confidence that the ambulance officer is likely to make a diagnosis that correctly reports no-STEMI when in fact there is no-STEMI. In addition, specificity can be decreased when the cost of additional diagnostic testing is low. To this end, it is reasonable to increase sensitivity at the expense of specificity when the ramifications of missing a STEMI are so high.

With overall results showing a final sensitivity of 84.3% and a specificity of 53.5%, a high sensitivity and a low specificity inform that a STEMI will rarely be missed for those with the condition. However, there is a potential to over-diagnose a high number of patients if too many false-positives are recorded within a low specificity. Low PPV further highlights a tendency for the ambulance officer to overestimate those who have actual STEMI. The balance of risk, however, suggests that the low level of PPV and specificity may be acceptable when the patient is suspected of having a STEMI. The downside to this is the potential complications to the wider system of care.

5.8 Theoretical Contribution to the New Zealand System of Care

Timely diagnosis and prompt intervention are essential factors in ensuring optimal outcome for those with STEMI. The time of symptom onset to definitive treatment is crucial to the degree of myocardial damage, cell loss and subsequent morbidity and mortality (Ioannidis, Salem, Chew & Lau 2001). Imperative to early treatment is the correct identification of STEMI within the prehospital environment. Within a New Zealand context, ambulance officers are key treatment providers for STEMI and offer a potential for early diagnosis, subsequent treatment and may help reduce myocardial damage.

Accurate prehospital ECG diagnosis can decrease door-to-balloon and door-to-needle times by as much as 20 minutes (Brown, Mahmud, Dunford, & Ben-Yehuda, 2008). Those referred by ambulance direct to the cardiac catheterisation laboratory reported improved times to treatment (Rathore et al., 2009) and reduced in-hospital mortality (Le May et al., 2010). The findings of this study and those of Feldman et al. (2005), Le May et al. (2006b) and Trivedi et al. (2009) support interpretation of prehospital 12-lead ECG to help facilitate an efficient system of care. However, the high number of false-positives found within our study have potential implications for the New Zealand system of care.

The goal of early STEMI management is to not miss the diagnosis of STEMI. However, a false-positive diagnosis by the ambulance officer can promote risk and complication. Le May et al. (2006b) found a decrease in diagnostic accuracy when their ambulance officers were asked if they would administer thrombolytic therapy to the suspected STEMI. Here, the PPV dropped from 82% (95% CI, 71 to 90) to 73% (95% CI, 59 to 85) which would have resulted in some not being administered thrombolytic therapy. The result reported by Ducas et al. (2012) suggests that given the risks involved with thrombolytic therapy, a PPV of 60% (95% CI, 54 to 64) should be deemed ‘unacceptably low’.

In contrast to our study, both Ducas et al. (2012) and May et al. (2006b) removed levels of complexity to their investigation by providing prior training and excluding STEMI mimic. The findings of this study report a PPV of 29.9% and highlight a point of caution for the administration of prehospital thrombolytic therapy based on ambulance officer 12-lead ECG interpretation. Given our result, a significant number of patients

without STEMI would potentially have been administered inappropriate thrombolytic therapy.

High numbers of false-positive STEMI diagnosis were found in this study and those of Ducas et al. (2012) and Mencl et al. (2013). There is a potential to place a patient at risk following inappropriate administration of thrombolytic therapy and the balance of risk versus benefit is surely lost with the low specificity and PPV found within this study. In addition, the possibility of hospital bypass and autonomous activation of the cardiac catheterisation laboratory by an ambulance officer should be considered carefully as this may have inappropriate resource utilisation and financial implications should a system be developed within the Auckland region.

It is important to recognise the importance of early STEMI diagnosis and reflect on the question of how applicable the results of this report are. This analysis included ambulance officers who had no prior guidance or training to influence the study or outcome and therefore reduce any potential 'Hawthorne effect'. This study was based on data that was uninfluenced by a prior training package and provided a retrospective representation of the ambulance officers ability to identify STEMI over a three-month period in 2016. The question of the accuracy of STEMI diagnosis by ambulance officers within the Auckland region was addressed and the complexity and influence that may help or hinder the correct diagnosis were investigated.

This study highlights several important aspects regarding the current prehospital system of care within New Zealand. The diagnosis of STEMI by ambulance officers within the prehospital environment is possible, but there remains a high level of incorrect diagnosis for this to support a truly autonomous model. This research provides an understanding of current clinical knowledge and practice and could inform policy, education, future research opportunities and most importantly clinical practice.

5.9 Limitations

While this study was well designed and employed robust methods, there are a number of limitations to be considered. Due to the retrospective nature of this study, a potential cause for any associated diagnostic false grouping cannot be drawn. In addition, it is possible that there are many factors that may be implicated toward a limitation to the results of this study. An example is that there was a relatively high proportion of unmatched hospital cases to ambulance data (Figure 5). With 23/123 hospital records

not matching ambulance data, there is a potential data collection issue due to a multi-agency approach to data gathering. Variables that were collected and could potentially influence the accuracy will, therefore, be discussed below.

The referral from a healthcare facility and the associated ambulance officer diagnosis is reported as an important finding within this report. Healthcare facilities provide referral by a registered healthcare professional such as doctor or nurse from within a medical centre, retirement home or treatment facility. The different variables present uncertainty as to who made the initial diagnosis with data collection by St John ambulance not routinely recording prior diagnosis. Whilst important to understand the extent of the influence made prior to the referral, it was beyond the capacity of the current study to gain this detail. Therefore, the influence of the referring healthcare professionals was examined in general terms and not by the profession or skill level.

Additional potential limitations of the study are that it is not routinely reported within the ambulance data as to what treatments were provided prior to their arrival. For example, it is possible that some treatments such as aspirin, IV and morphine were provided by the patient's doctor prior to the ambulance arrival. This has the potential to alter the findings of this report as aspects of management were analysed based on ambulance officer treatment and not the referring healthcare professional. Documentation is an important way that healthcare professionals record and communicate the continuity of care provided to a patient within various settings. Consequently, ambulance service operating procedures assume undocumented actions or observations were not undertaken. It is therefore reasonable for this study to adopt this position and assume that if treatment was not recorded as being provided (by any person) then that treatment was not carried out.

The ambulance officer may have correctly identified a STEMI, only for the STEMI ECG presentation to resolve after arrival at hospital. The validation of the ambulance officer 12-lead ECG in relation to the interpretation was not investigated but relied upon hospital final diagnosis and subsequent requirement for reperfusion therapy. The data did not account for a resolving 'transient STEMI': 'd to e', (Figure 7), coronary vasospasm (Prinzmetal's angina) or those with STEMI but contraindicated for reperfusion therapy. This may have resulted in false-positive diagnosis data due to a reasonable prehospital ECG diagnosis of STEMI that resolved and was later diagnosed as Non-STEMI or not requiring intervention.

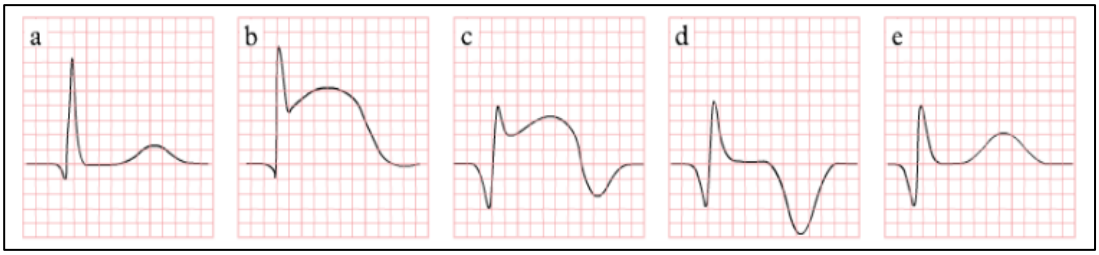


Figure 7 Stages of STEMI Development on the ECG (Evolving to Resolved).

A potential influencing factor for diagnostic agreement was that the ambulance officers 12-lead ECG were not compared to the cardiologist's ECG. This may represent a bias as an early prehospital diagnosis of no-STEMI, has the potential to later evolve into STEMI. The initial stages of an AMI may not match STEMI criteria due to the stage at which the ST segment is evolving (Figure 7). The interpretation for STEMI is not initially clear in the early stages: (a) and may only provide a determinable diagnostic change that met STEMI criteria when at 'b to c'. In this instance, it is possible for STEMI to develop/evolve after the ambulance officer has transferred the patient to the hospital (Krucoff et al., 1993). This may result in a False-negative diagnosis by the ambulance officer.

It is possible that incomplete or incorrect documentation has led to the under-reporting of ambulance officer diagnosis of STEMI. With a limited number of false-negative cases (n = 8), two cases provided an ECG interpretation of STEMI and remained false-negative. In this instance, both cases did not record a cardiac clinical impression of acute coronary syndrome. Whilst the criteria could be interpreted as too narrow for inclusion, ambulance officer notes and end diagnostic impression for these cases were reviewed and did not report any further reference to acute coronary syndrome or STEMI. It is possible that the ambulance officer recognised the acute coronary syndrome but did not provide this information within the ePRF documentation. Equally, it is possible that they were not confident enough to declare STEMI. Due to the nature of this study, it was impossible to understand what the actual intent was for these cases with documentation offering little certainty to a diagnosis of STEMI. Therefore, where there was a lack of detail and/or elements of uncertainty, the position adopted by this study is that the intent was not for a diagnosis of STEMI.

There may be data bias toward the qualification of the ambulance officer making the diagnosis. Within the metropolitan area of Auckland, an ambulance is crewed by two or more ambulance officers working at potentially different practice levels. The crew are therefore encouraged to ensure the interpretation of ECG is a collegial event with discussion and opinion being sought. However, the analysis of ECG interpretation for this study is based on the highest practice level recorded within the ePRF system rather than the practice level of who made the diagnosis. Whilst potentially a collegial interpretation it is anticipated that the highest practice level will have the greatest influence in the interpretation of the ECG and was therefore seen as reasonable to utilise the recorded qualification.

There were constraints to the methodology that should be considered when interpreting the results of this thesis. The results may no longer be representative of the Auckland ambulance officer cohort with demographics, education and practice level continually changing as more tertiary level ambulance officers are being employed. In addition, a 12-lead STEMI education training package was provided to all staff in 2017. Therefore, the basis of thesis conclusion may differ following the delivery of this focused training.

A prospective cohort study design to measure a patient's 30-day survival in relation to ambulance officer STEMI diagnosis versus missed-diagnosis was considered. This was not possible however as mortality data was not collected by the ambulance service at the time of data collection. In addition, a requirement for large case numbers and a potential lengthy timeframe to reach statistical significance was unfeasible. Therefore, due to the availability of existing data, the selected design is seen as an acceptable choice with effective use of the information available.

Finally, while this study represents a view of the data within the constraints of the Auckland geographic area, the findings may not be representative of the New Zealand ambulance officer cohort. Due to the small sample size, and being only three months in duration, small changes could have a large effect on the results. A larger study may provide greater accuracy and may detect changes and influence with greater certainty.

5.10 Generalisability

The domain of ambulance officers in the prehospital environment is both challenging and unique, requiring explicit care to produce meaningful research findings. There are fundamental differences that exist between countries, especially with regard to training

and education. This difference is likely to impact on the generalisability of international research findings to that of New Zealand.

Population-based studies that include New Zealand prehospital ambulance officers are extremely rare. There are many strengths that enhance the findings of this study. This study is characterised by a robust design and precise methods of data collection and diagnostic criteria. The generalisability of this result is limited by the extent to which the Auckland geographical region is representative of the greater New Zealand ambulance workforce. Certain features within the local setting may have impacted on the transferability of results to other regions within New Zealand. These include population, ambulance workforce, the availability and distance to the nearest cardiac catheterisation laboratory and national geography.

Auckland has a diverse multicultural population and this may not be representative of the wider New Zealand demographic profile. A further factor that must be considered is that the generalisability of the ambulance workforce would be greater in locations with similar levels of practice. Results may be different however, where the service delivery model is predominantly EMT or PARA. In addition, with the potential for limited opening hours and/or extensive transport times to an available cardiac catheterisation laboratory, results may be different due management options available for STEMI (Antman et al., 2008; Steg et al., 2012).

5.11 Future Research and Implications for Practice

The amount of ambulance officer misdiagnosis of STEMI observed in this study requires further review. The level of false-positive STEMI diagnosis found within this study relay doubt as to the safety for autonomous hospital bypass, early activation of the catheterization laboratory and provision of autonomous thrombolytic therapy by an ambulance officer. Policy and structure need to be developed to inform a safe and effective treatment pathway that allows for aspects of false-positive diagnosis of STEMI without added risk. Until the level of false-positives is investigated and reduced, it would be erroneous to recommend such a protocol within the prehospital setting.

This thesis did not investigate if those patients within the ‘false-negative’ group had differing mortality or morbidity outcomes in comparison to those within other diagnostic groups. Within the New Zealand context, it is unknown if the delayed prehospital diagnosis for this group resulted in risk. A future study would help to

determine the relative risk involved with outcome and mortality of those not recognised with STEMI by the ambulance officer.

Numerous international studies have reported that patients do not recognise nor understand the symptoms of acute myocardial infarction, nor do they initiate ambulance support (Bray, Straney, Patsamanis, Stavreski, & Finn, 2016; Tummala & Farshid, 2015). This thesis reported that 30.9% of all those diagnosed with STEMI between 1st April 2016 and 30th June 2016 did not call for emergency ambulance assistance, but rather made their own way to the hospital (*Figure* 5). This may relate to public awareness of STEMI symptom, ambulance resource limitations or more worryingly, patient finance. An investigation into those who self-present may provide an understanding as to why they did not call an ambulance. This is important, especially when looking at the unique demographic population of New Zealand. This may inform public policy, and encourage those with potential cardiac-related symptoms to understand the benefit of early prehospital treatments and direct admission toward a hospital with interventional facilities.

From an international perspective, there are several ambulance services that offer additional STEMI diagnostic tools such as point of care blood testing (Husson, Pauchet, Decoulx, & Goldstein, 2018). This can offer a potential advantage, as diagnostic testing is currently not found within the New Zealand ambulance context. A potential future research opportunity would be to investigate the cost-effectiveness and implementation of such tests in relation to the prehospital diagnostic accuracy of STEMI.

The findings of the present study suggest that those patients transported from a Healthcare facility show significant over-estimation for the diagnosis of STEMI by the ambulance officer. It is unknown why this is an influential factor in the misdiagnosis of STEMI and could be investigated to establish trends and the potential cause.

All but one of the studies found within the literature review highlighted prior focused STEMI education toward the ambulance officer cohort, Table 7. This thesis investigated retrospective data to determine Auckland ambulance officer STEMI accuracy between 1st April 2016 and 30th June 2016. In 2017, all ambulance officers employed by St John ambulance were provided with an online training package designed to educate on STEMI diagnosis. This package was delivered after the thesis data collection period and offers some interest as to the effectiveness of that training and whether results shown within this report are consistent with today’s ambulance officer STEMI accuracy. The

implications for future practice would be to compare the results of this study with those following the educational update. This will allow identification of deficit and inform on the effectiveness of the training.

Finally, when compared to NZ Europeans, those of Asian ethnicity were less likely to have hospital diagnostic agreement (AOR 0.30, 95% CI: 0.09 to 0.98, $p = 0.05$). In addition, half of all missed STEMI (false-negatives) were identified in people of Asian ethnicity (Table 12). Given the small number of cases (n=35) (Table 12), there are limitations in being able to offer a clear understanding to this association as the likelihood of a 'chance' finding as a consequence of the small sample is possible. One possible explanation, however, is that there was a 'fundamental attribution error' on the part of the ambulance officer. All cases were transported from home, with the majority complaining of chest pain and deemed to be Status Two in severity. It is possible that distribution qualities of a person or group rather than the situation and its circumstances reflect a lack of understanding or are complicated by a language barrier. Whilst it is impossible to fully understand the circumstances that influenced the incorrect diagnosis found in this study, cultural differences and language may have contributed. This is an area that is outside of the analysis of this study and offers a potential opportunity for future research.

Chapter 6 CONCLUSION

This thesis represents the first New Zealand study to establish the accuracy of STEMI diagnosis by the ambulance officer when compared to cardiologist diagnosis without the exclusion of STEMI mimic. The study adopted a unique ambulance officer perspective and employed a retrospective quantitative approach to provide a greater understanding of STEMI diagnostic accuracy without implementing additional refresher training. The two main objectives were as follows.

The primary outcome was to investigate the accuracy of the ambulance officer STEMI diagnosis by measuring the sensitivity, specificity, PPV and NPV. In this study, the sensitivity of 84.3% identifies that an ambulance officer will rarely miss a STEMI for those patients who do have the condition. However, the low specificity recorded (53.5%) reveals that there is a potential to over-diagnose patients as evidenced by the high proportion that were false-positive. A low PPV of 29.9% further emphasizes a tendency for the ambulance officer to overestimate those who have actual STEMI. The NPV result indicates that of the patients that were ambulance-negative, 93.6% were also confirmed as hospital-negative.

This study highlights potential for incorrect early activation or bypass to the catheterization laboratory and inappropriate administration of thrombolytic therapy. Whilst the further investigation into ‘false-positive’ diagnosis is required, the balance of risk suggests that the low levels of both specificity and PPV may be acceptable when the patient is suspected of having a STEMI. The downside to this is the potential inefficiency to the wider system of care and a risk to the patient of an adverse event following prehospital ambulance-initiated thrombolysis.

The second objective was to identify predictors of ambulance and hospital diagnostic agreement. Ambulance officer and hospital diagnosis were associated with two main factors (predictors): the ambulance retrieval location and the patient symptom severity. When compared to the retrieval from the patient’s home, a patient transported by ambulance from a healthcare facility was three times less likely to have diagnostic agreement with the hospital. Finally, patients initially assessed with a clinical symptom severity of Status Two, when compared to those assessed at Status One, were less likely to have diagnostic agreement with a hospital. These factors have not previously been

reported within the literature but offer some insight into the unique nature of prehospital STEMI diagnosis.

In summary, the findings of the research proposition were mixed. The diagnosis of STEMI by ambulance officers within the prehospital environment is possible, but there remains a high level of incorrect diagnosis. This does not help support a truly autonomous ambulance service model that includes the initiation of hospital bypass or the administration of thrombolytics. Finally, this study provides new insight into ambulance officer practice and can be used to inform policy, education and most importantly, clinical practice of prehospital STEMI care in New Zealand.

REFERENCES

Adams, G., Abusaid, G., Lee, B., Maynard, C., Campbell, P., Wagner, G., & Barbagelata, A. (2010). From theory to practice: implementation of pre-hospital electrocardiogram transmission in ST-elevation myocardial infarction-a multicenter experience. *The Journal Of Invasive Cardiology, 22*(11), 520-525.

Al-Shaqsi, S. (2010). Models of International Emergency Medical Service (EMS) Systems. *Oman Med J, 25*(4), 320-323. doi:10.5001/omj.2010.92

Antman, E. M., Hand, M., Armstrong, P. W., Bates, E. R., Green, L. A., Halasyamani, L. K., . . . Mullany, C. J. (2008). 2007 Focused update of the ACC/AHA 2004 Guidelines for the Management of Patients With ST-Elevation Myocardial Infarction: a report of the American College of Cardiology/American Heart Association Task Force on Practice Guidelines: developed in collaboration with the Canadian Cardiovascular Society endorsed by the American Academy of Family Physicians: 2007 Writing Group to review new evidence and update the ACC/AHA 2004 Guidelines for the Management of Patients With ST-Elevation Myocardial Infarction, writing on behalf of the 2004 Writing Committee. *Circulation, 117*(2), 296-329.

Ayer, A., & Terkelsen, C. J. (2014). Difficult ECGs in STEMI: lessons learned from serial sampling of pre- and in-hospital ECGs. *Journal Of Electrocardiology, 47*(4), 448-458. doi:10.1016/j.jelectrocard.2014.03.010

Bagai, A., Jollis, J. G., Dauerman, H. L., Peng, S. A., Rokos, I. C., Bates, E. R., . . . Roe, M. T. (2013). Emergency Department Bypass for ST-Segment Elevation Myocardial Infarction Patients Identified with a Pre-Hospital Electrocardiogram: A Report From the American Heart Association Mission: Lifeline™ Program. *Circulation*, CIRCULATIONAHA. 113.002339.

Batt, A. M., Al-Hajeri, A. S., Delport, S., Jenkins, S. M., Norman, S. E., & Cummins, F. H. (2018). Implementation of an ST-segment elevation myocardial infarction bypass protocol in the Northern United Arab Emirates. *Heart views: the official journal of the Gulf Heart Association, 19*(4), 121.

Bernard, R. (1979). Nomenclature and criteria for diagnosis of ischemic heart disease. Report of the Joint International Society and Federation of Cardiology/World Health Organization task force on standardization of clinical nomenclature. *Circulation, 59*(3), 607-609. doi:10.1161/01.CIR.59.3.607

Bosson, N., Sanko, S., Stickney, R. E., Niemann, J., French, W. J., Jollis, J. G., ... & Koenig, W. (2017). Causes of prehospital misinterpretations of ST elevation myocardial infarction. *Prehospital Emergency Care*, *21*(3), 283-290.

Bray, J. E., Straney, L., Patsamanis, H., Stavreski, B., & Finn, J. (2016). Australian's Awareness of Heart Attack Symptoms and Action Improves With a Mass Media Warning Signs Campaign. *Circulation, 134*(Suppl_1), A20858.

Brown, J. P., Mahmud, E., Dunford, J. V., & Ben-Yehuda, O. (2008). Effect of prehospital 12-lead electrocardiogram on activation of the cardiac catheterization laboratory and door-to-balloon time in ST-segment elevation acute myocardial infarction. *The American Journal Of Cardiology, 101*(2), 158-161. doi:10.1016/j.amjcard.2007.07.082

Burgess, C. P., Bailie, R. S., Connors, C. M., Chenhall, R. D., McDermott, R. A., O'Dea, K., ... & Esterman, A. J. (2011). Early identification and preventive care for elevated cardiovascular disease risk within a remote Australian Aboriginal primary health care service. *BMC health services research*, *11*(1), 24.

Cardiac Society of Australia and New Zealand. (2013). ST-elevation myocardial infarction: New Zealand management guidelines.

Cheskes, S., Turner, L., Foggett, R., Huiskamp, M., Popov, D., Thomson, S., . . . Verbeek, R. (2011). Paramedic contact to balloon in less than 90 minutes: a successful strategy for st-segment elevation myocardial infarction bypass to primary percutaneous coronary intervention in a canadian emergency medical system. *Prehospital Emergency Care: Official Journal Of The National Association Of EMS Physicians And The National Association Of State EMS Directors, 15*(4), 490-498. doi:10.3109/10903127.2011.598613

Croskerry, P. (2002). Achieving quality in clinical decision making: cognitive strategies and detection of bias. *Academic Emergency Medicine, 9*(11), 1184-1204.

Davis, D. P., Graydon, C., Stein, R., Wilson, S., Buesch, B., Berthiaume, S., . . . Leahy, D. R. (2007). The positive predictive value of paramedic versus emergency physician interpretation of the prehospital 12-lead electrocardiogram. *Prehospital Emergency Care: Official Journal Of The National Association Of EMS Physicians And The National Association Of State EMS Directors, 11*(4), 399-402.

Davis, P. (2018). *New Zealand paramedic-based systems of care for ST-elevation myocardial infarction patients: Autonomous delivery of fibrinolytic treatment and cardiac catheterisation laboratory referral*. Auckland University of Technology.

Dicker, B., Howie, G., & Tunnage, B. (2017). *Out-of-hospital cardiac arrest registry: Annual report 2016/17. St john new zealand*. Retrieved from https://www.stjohn.org.nz/Search/?quicksearchquery=Out-of-hospital+cardiac+arrest+registry:+Annual+report+2016/17

Diercks, D. B., Kontos, M. C., Chen, A. Y., Pollack, C. V., Jr., Wiviott, S. D., Rumsfeld, J. S., . . . Roe, M. T. (2009). Utilization and impact of pre-hospital electrocardiograms for patients with acute ST-segment elevation myocardial infarction: data from the NCDR (National Cardiovascular Data Registry) ACTION (Acute Coronary Treatment and Intervention Outcomes Network) Registry. *Journal Of The American College Of Cardiology, 53*(2), 161-166. doi:10.1016/j.jacc.2008.09.030

Ducas, R. A., Wassef, A. W., Jassal, D. S., Weldon, E., Schmidt, C., Grierson, R., & Tam, T. W. (2012). To transmit or not to transmit: how good are emergency medical personnel in detecting STEMI in patients with chest pain? *The Canadian Journal Of Cardiology, 28*(4), 432-437. doi:10.1016/j.cjca.2012.04.008

Feldman, J. A., Brinsfield, K., Bernard, S., White, D., & Maciejko, T. (2005). Real-time paramedic compared with blinded physician identification of ST-segment elevation myocardial infarction: results of an observational study. *The American Journal Of Emergency Medicine, 23*(4), 443-448.

Feringa, H. H., van Waning, V. H., Bax, J. J., Elhendy, A., Boersma, E., Schouten, O., Poldermans, D. (2006). Cardioprotective medication is associated with improved survival in patients with peripheral arterial disease. *Journal Of The American College Of Cardiology, 47*(6), 1182-1187.

Fukuoka, Y., Dracup, K., Moser, D. K., McKinley, S., Ball, C., Yamasaki, K., & Kim, C. J. (2007). Is severity of chest pain a cue for women and men to recognize acute myocardial infarction symptoms as cardiac in origin? *Progress in cardiovascular nursing, 22*(3), 132-137.

Garvey, J. L., MacLeod, B. A., Sopko, G., & Hand, M. M. (2006). Pre-hospital 12-lead electrocardiography programs: a call for implementation by emergency medical services systems providing advanced life support--National Heart Attack Alert Program (NHAAP) Coordinating Committee; National Heart, Lung, and Blood

Institute (NHLBI); National Institutes of Health. *Journal Of The American College Of Cardiology, 47*(3), 485-491.

Gearing, R. E., Mian, I. A., Barber, J., & Ickowicz, A. (2006). A methodology for conducting retrospective chart review research in child and adolescent psychiatry. *Journal of the Canadian Academy of Child and Adolescent Psychiatry, 15*(3), 126.

Halperin, J. L., Levine, G. N., Al-Khatib, S. M., Birtcher, K. K., Bozkurt, B., Brindis, R. G., Gentile, F. (2016). Further evolution of the ACC/AHA clinical practice guideline recommendation classification system: a report of the American College of Cardiology/American Heart Association Task Force on Clinical Practice Guidelines. *Circulation, 133*(14), 1426-1428.

Hamer, K.L., Wong, B., Renner, C., Wong, C. K., Ellis, C., Nunn, C., Smyth, D., Devlin, G., Wilkins, G., Armstrong, G., Hart. H., White, H., Patel, H., & Crozier, I. ST-Elevation, M. I. G. G. (2013). ST-elevation myocardial infarction: New Zealand Management Guidelines, 2013. *The New Zealand medical journal, 126*(1387), 127.

Hay, S. I., Jayaraman, S. P., Truelsen, T., Sorensen, R. J., Millear, A., Giussani, G., & Beghi, E. (2017). GBD 2015 Disease and Injury Incidence and Prevalence Collaborators. Global, regional, and national incidence, prevalence, and years lived with disability for 310 diseases and injuries, 1990-2015: a systematic analysis for the Global Burden of Disease Study 2015 (vol 388, pg 1545, 2016). *Lancet, 389*(10064), E1-E1.

Hemsey, J. Z., Dracup, K., Fleischmann, K., Sommargren, C. E., & Drew, B. J. (2012). Pre-hospital 12-Lead ST-Segment Monitoring Improves the Early Diagnosis of Acute Coronary Syndrome. *J Electrocardiol, 45*(3), 266-271. doi:10.1016/j.jelectrocard.2011.10.004

Hennekens, C. H., & Buring, J. E. (1987). *Epidemiology in medicine* (Vol. 255): Little, Brown Boston.

Huber, K., Caterina, R. D., Kristensen, S. D., Verheugt, F. W., Montalescot, G., Maestro, L. B., & Werf, F. V. d. (2005). Pre-hospital reperfusion therapy: a strategy to improve therapeutic outcome in patients with ST-elevation myocardial infarction. *European Heart Journal, 26*(19), 2063-2074.

Huitema, A. A., Zhu, T., Alemayehu, M., & Lavi, S. (2014). Diagnostic accuracy of ST-segment elevation myocardial infarction by various healthcare providers. *International Journal Of Cardiology, 177*(3), 825-829. doi:10.1016/j.ijcard.2014.11.032

Husson, K., Pauchet, N., Decoulx, B., & Goldstein, P. (2018). Interest and value of point of care test in pre-hospital setting. *Sang Thrombose Vaisseaux, 30*(1), 21-25.

Hutchison, A. W., Malaiapan, Y., Cameron, J. D., & Meredith, I. T. (2013). Pre-hospital 12 lead ECG to triage ST elevation myocardial infarction and long term improvements in door to balloon times: The first 1000 patients from the MonAMI project. *Heart, Lung and Circulation, 22*(11), 910-916.

Ibanez, B., James, S., Agewall, S., Antunes, M. J., Bucciarelli-Ducci, C., Bueno, H., ... & Hindricks, G. (2017). 2017 ESC Guidelines for the management of acute myocardial infarction in patients presenting with ST-segment elevation: The Task Force for the management of acute myocardial infarction in patients presenting with ST-segment elevation of the European Society of Cardiology (ESC). *European heart journal, 39*(2), 119-177.

Ioannidis, J. P., Salem, D., Chew, P. W., & Lau, J. (2001). Accuracy and clinical effect of out-of-hospital electrocardiography in the diagnosis of acute cardiac ischemia: a meta-analysis. *Annals Of Emergency Medicine, 37*(5), 461-470.

Jacobs, A. K., Kushner, F. G., Ettinger, S. M., Guyton, R. A., Anderson, J. L., Ohman, E. M., . . . Bertolet, M. (2013). ACCF/AHA clinical practice guideline methodology summit report: a report of the American College of Cardiology Foundation/American Heart Association Task Force on Practice Guidelines. *Journal Of The American College Of Cardiology, 61*(2), 213-265.

Kassirer, J. P., Kopelman, R. I., & Wong, J. B. (1991). *Learning clinical reasoning*: Williams & Wilkins Baltimore.

Keeley, E. C., Boura, J. A., & Grines, C. L. (2003). Primary angioplasty versus intravenous thrombolytic therapy for acute myocardial infarction: a quantitative review of 23 randomised trials. *The lancet, 361*(9351), 13-20.

Kip, M. M., Koffijberg, H., Moesker, M. J., IJzerman, M. J., & Kusters, R. (2017). The cost-utility of point-of-care troponin testing to diagnose acute coronary syndrome in primary care. *BMC cardiovascular disorders, 17*(1), 213.

Krucoff, M. W., Croll, M. A., Pope, J. E., Pieper, K. S., Kanani, P. M., Granger, C. B., . . . Califf, R. M. (1993). Continuously updated 12-lead ST-segment recovery analysis for myocardial infarct artery patency assessment and its correlation with multiple simultaneous early angiographic observations. *American Journal of Cardiology, 71*(2), 145-151.

Le May, M. R., Davies, R. F., Dionne, R., Maloney, J., Trickett, J., So, D., . . . Labinaz, M. (2006a). Comparison of early mortality of paramedic-diagnosed ST-segment elevation myocardial infarction with immediate transport to a designated primary percutaneous coronary intervention center to that of similar patients transported to the nearest hospital. *The American Journal Of Cardiology, 98*(10), 1329-1333.

Le May, M. R., Dionne, R., Maloney, J., Trickett, J., So, D., . . . Labinaz, M. (2006b). Diagnostic performance and potential clinical impact of advanced care paramedic interpretation of ST-segment elevation myocardial infarction in the field. *Canadian Journal of Emergency Medicine, 8*(6), 401-407.

Le May, M. R., Dionne, R., Maloney, J., & Poirier, P. (2010). The role of paramedics in a primary PCI program for ST-elevation myocardial infarction. *Progress In Cardiovascular Diseases, 53*(3), 183-187. doi:10.1016/j.pcad.2010.08.003

Leman, P., & Morley, P. (2016). Updated resuscitation guidelines for 2016: A summary of the Australian and New Zealand Committee on Resuscitation recommendations. *Emergency Medicine Australasia, 28*(4), 379-382.

Li, J., Li, X., Wang, Q., Hu, S., Wang, Y., Masoudi, F. A., ... & China PEACE Collaborative Group. (2015). ST-segment elevation myocardial infarction in China from 2001 to 2011 (the China PEACE-Retrospective Acute Myocardial Infarction Study): a retrospective analysis of hospital data. *The Lancet, 385*(9966), 441-451.

Mencl, F., Wilber, S., Frey, J., Zalewski, J., Maiers, J. F., & Bhalla, M. C. (2013). Paramedic ability to recognize ST-segment elevation myocardial infarction on prehospital electrocardiograms. *Prehospital Emergency Care: Official Journal Of The National Association Of EMS Physicians And The National Association Of State EMS Directors, 17*(2), 203-210. doi:10.3109/10903127.2012.755585

Ministry of Health. (2004). Ethnicity data protocols for the health and disability sector. *Wellington, New Zealand: Ministry of Health*.

Ministry of Health. (2011). *Targeting diabetes and cardiovascular disease*. Retrieved from https://www.health.govt.nz/publication/targeting-diabetes-and-cardiovascular-disease

Ministry of Health. (2015). *Mortality and demographic data 2013*. Retrieved from https://www.health.govt.nz/nz-health-statistics/health-statistics-and-data-sets/mortality-and-demographic-data-series

Ministry of Health. (2018). New Zealand health survey: Annual update of key results 2017/18. Retrieved from https://www.health.govt.nz/publication/annual-update-key-results-2017-18-new-zealand-health-survey

Moher, Liberati, A., Tetzlaff, J., & Altman, D. G. (2010). Preferred reporting items for systematic reviews and meta-analyses: the PRISMA statement. *International journal of surgery, 8*(5), 336-341.

Nolan, J. P., Hazinski, M. F., Aickin, R., Bhanji, F., Billi, J. E., Callaway, C. W., . . . Finn, J. C. (2015). Part 1: executive summary: 2015 international consensus on cardiopulmonary resuscitation and emergency cardiovascular care science with treatment recommendations. *Resuscitation, 95*, e1-e31.

O'Donnell, D., Mancera, M., Savory, E., Christopher, S., Schaffer, J., & Roumpf, S. (2015). The availability of prior ECGs improves paramedic accuracy in recognizing ST-segment elevation myocardial infarction. *Journal of electrocardiology, 48*(1), 93-98.

Olasveengen, T. M., de Caen, A. R., Mancini, M. E., Maconochie, I. K., Aickin, R., Atkins, D. L., . . . Castrén, M. (2017). 2017 International consensus on cardiopulmonary resuscitation and emergency cardiovascular care science with treatment recommendations summary. *Resuscitation, 121*, 201-214.

Pallant, J. (2013). *SPSS survival manual*: McGraw-Hill Education (UK).

Pannucci, C. J., & Wilkins, E. G. (2010). Identifying and avoiding bias in research. *Plastic and reconstructive surgery, 126*(2), 619.

Paradis, E., & Sutkin, G. (2017). Beyond a good story: from Hawthorne Effect to reactivity in health professionals education research. *Medical education*, 5(1), 31-39.

Pilbery, R., Teare, M. D., Goodacre, S., & Morris, F. (2016). The Recognition of STEMI by Paramedics and the Effect of Computer inTerpretation (RESPECT): a randomised crossover feasibility study. *Emergency Medicine Journal: EMJ, 33*(7), 471-476. doi:10.1136/emermed-2015-204988

Rab, T., Kern, K. B., Tamis-Holland, J. E., Henry, T. D., McDaniel, M., Dickert, N. W., . . . Ramee, S. (2015). Cardiac arrest: a treatment algorithm for emergent invasive cardiac procedures in the resuscitated comatose patient. *Journal Of The American College Of Cardiology, 66*(1), 62-73.

Rao, A., Kardouh, Y., Darda, S., Desai, D., Devireddy, L., Lalonde, T., . . . David, S. (2010). Impact of the prehospital ECG on door-to-balloon time in ST elevation myocardial infarction. *Catheterization And Cardiovascular Interventions: Official Journal Of The Society For Cardiac Angiography & Interventions, 75*(2), 174-178. doi:10.1002/ccd.22257

Rathore, S. S., Curtis, J. P., Chen, J., Wang, Y., Nallamothu, B. K., Epstein, A. J., & Krumholz, H. M. (2009). Association of door-to-balloon time and mortality in patients admitted to hospital with ST elevation myocardial infarction: national cohort study. *Bmj, 338*, b1807.

Reffelmann, T., Hale, S. L., Li, G., & Kloner, R. A. (2002). Relationship between no reflow and infarct size as influenced by the duration of ischemia and reperfusion. *American Journal of Physiology-Heart and Circulatory Physiology, 282*(2), H766-H772.

Ringstrom, E., & Freedman, J. (2006). Approach to Undifferentiated Chest Pain in the Emergency Department. *The Mount Sinai journal of medicine, 73*(2), 499.

Roth, G. A., Forouzanfar, M. H., Moran, A. E., Barber, R., Nguyen, G., Feigin, V. L., . . . Murray, C. J. L. (2015). Demographic and Epidemiologic Drivers of Global Cardiovascular Mortality. *New England Journal of Medicine, 372*(14), 1333-1341. doi:10.1056/NEJMoa1406656

Scholz, K. H., von Knobelsdorff, G., Ahlersmann, D., Keating, F. K., Jung, J., Werner, G. S., . . . Hilgers, R. (2008). Optimizing systems of care for patients with acute myocardial infarction. STEMI networks, telemetry ECG, and standardized quality improvement with systematic data feedback. *Herz, 33*(2), 102-109.

Shams, M., Sullivan, A., Abudureyimu, S., Hassouna, B., Jayanthi, V., Amdur, R., . . . Mercader, M. (2016). Optimizing electrocardiogram interpretation and catheterization laboratory activation in ST-segment elevation myocardial infarction: A teaching module for medical students. *Journal Of The American College Of Cardiology, 67*(13 Supplement), 643.

So, D. Y., Ha, A. C., Turek, M. A., Maloney, J. P., Higginson, L. A., Davies, R. F., . . . Le May, M. R. (2006). Comparison of mortality patterns in patients with ST-elevation myocardial infarction arriving by emergency medical services versus self-transport (from the prospective Ottawa Hospital STEMI Registry). *American Journal of Cardiology, 97*(4), 458-461.

Statistics New Zealand. (2017). *New Zealand in Profile: 2015*. Retrieved from *http://www. stats. govt. nz/browse_for_stats/snapshots-of-nz/nz-in-profile-2015/imports-exports. aspx*.

Steg, P. G., James, S. K., Atar, D., Badano, L. P., Lundqvist, C. B., Borger, M. A., . . . Ducrocq, G. (2012). ESC Guidelines for the management of acute myocardial infarction in patients presenting with ST-segment elevation: The Task Force on the management of ST-segment elevation acute myocardial infarction of the European Society of Cardiology (ESC). *European Heart Journal, 33*(20), 2569-2619.

Tanguay, A., Brassard, E., Lebon, J., Bégin, F., Hébert, D., & Paradis, J.-M. (2017). Effectiveness of a Prehospital Wireless 12-Lead Electrocardiogram and Cardiac Catheterization Laboratory Activation for ST-Elevation Myocardial Infarction. *The American Journal Of Cardiology, 119*(4), 553-559. doi:10.1016/j.amjcard.2016.10.042

Thygesen, K., Alpert, J. S., Jaffe, A. S., Simoons, M. L., Chaitman, B. R., White, H. D., . . . Alpert, J. S. (2012). Third universal definition of myocardial infarction. *European Heart Journal, 33*(20), 2551-2567.

Travers, A., Rea, T., Bobrow, B., Edelson, D., & Berg, R. (2010). Part 4: CPR Overview: 2010 American Heart Association Guidelines for Cardiopulmonary Resuscitation and Emergency Cardiovascular Care. Circulation, 122, S676-S684.

Trivedi, K., Schuur, J. D., & Cone, D. C. (2009). Can paramedics read ST-segment elevation myocardial infarction on prehospital 12-lead electrocardiograms? *Prehospital Emergency Care: Official Journal Of The National Association Of EMS Physicians And The National Association Of State EMS Directors, 13*(2), 207-214. doi:10.1080/10903120802706153

Tummala, S. R., & Farshid, A. (2015). Patients' understanding of their heart attack and the impact of exposure to a media campaign on pre-hospital time. *Heart, Lung and Circulation, 24*(1), 4-10.

Vandenbroucke, J. P., von Elm, E., Altman, D. G., Gøtzsche, P. C., Mulrow, C. D., Pocock, S. J., . . . Egger, M. (2014). Strengthening the Reporting of Observational Studies in Epidemiology (STROBE): explanation and elaboration. *International journal of surgery, 12*(12), 1500-1524.

Verheugt, F. W., Gersh, B. J., & Armstrong, P. W. (2006). Aborted myocardial infarction: a new target for reperfusion therapy. *European Heart Journal, 27*(8), 901-904.

Whitbread, M., Leah, V., Bell, T., & Coats, T. (2002). Recognition of ST elevation by paramedics. *Emergency Medicine Journal, 19*(1), 66-67.

Wong, D. L., & Baker, C. M. (2001). Smiling face as anchor for pain intensity scales. *Pain*, *89*(2), 295-297.

Yeh, R. W., Sidney, S., Chandra, M., Sorel, M., Selby, J. V., & Go, A. S. (2010). Population trends in the incidence and outcomes of acute myocardial infarction. *New England Journal of Medicine*, *362*(23), 2155-2165.

Glossary of Terms

Abbreviation		Term
ACC	=	American Cardiovascular Care
ACS	=	Acute coronary syndrome
AHA	=	American Heart Association
AMI	=	Acute myocardial infarction
ANZCOR	=	Australian and New Zealand Committee on Resuscitation
AOR	=	Adjusted Odds Ratio
BBB	=	Bundle branch block
CoSTR.	=	Consensus on Cardiopulmonary Resuscitation and Emergency Cardiovascular Care with Treatment Recommendations
CPR	=	Cardiopulmonary resuscitation
DOB	=	Date of Birth
ECG	=	Electrocardiogram
EMT	=	Emergency medical technician
ePRF	=	Electronic patient report form
FN	=	False-negative
FP	=	False-positive
GTN	=	Glycerol Trinitrate
HOSP	=	Hospital
IBM	=	International business machines
ICP	=	Intensive care paramedic
ILCOR	=	International Liaison Committee on Resuscitation
IV	=	Intravenous
LBBB	=	Left bundle branch block
LOE	=	Level of evidence
NPV	=	Negative predictive value

NRA	=	Northern Regional Alliance
PARA	=	Paramedic
PCI	=	Percutaneous coronary intervention
PPV	=	Positive predictive value
PRISMA	=	Preferred Reporting Items for Systematic Reviews and Meta-Analyses
RCT	=	Randomised controlled trial
RBBB	=	Right bundle branch block
SPSS	=	Statistical package for social sciences
STEMI	=	ST-elevation myocardial infarction
STROBE	=	STrengthening the Reporting of OBservational studies in Epidemiology
UOR	=	Unadjusted Odds Ratio
WHO	=	World Health Organisation

Appendices

Appendix A: AUTEC Approval Letter

Auckland University of Technology Ethics Committee approval

14 November 2016

Paul Davey
Faculty of Health and Environmental Sciences

Dear Paul

Re Ethics Application: **16/392 Pre-hospital STEMI recognition: An Auckland retrospective study**

Thank you for providing evidence as requested, which satisfies the points raised by the Auckland University of Technology Ethics Sub-Committee (AUTEC).

Your ethics application has been approved for three years until 14 November 2019.

As part of the ethics approval process, you are required to submit the following to AUTEC:

- A brief annual progress report using form EA2, which is available online through http://www.aut.ac.nz/researchethics. When necessary this form may also be used to request an extension of the approval at least one month prior to its expiry on 14 November 2019;
- A brief report on the status of the project using form EA3, which is available online through http://www.aut.ac.nz/researchethics. This report is to be submitted either when the approval expires on 14 November 2019 or on completion of the project.

It is a condition of approval that AUTEC is notified of any adverse events or if the research does not commence. AUTEC approval needs to be sought for any alteration to the research, including any alteration of or addition to any documents that are provided to participants. You are responsible for ensuring that research undertaken under this approval occurs within the parameters outlined in the approved application.

AUTEC grants ethical approval only. If you require management approval from an institution or organisation for your research, then you will need to obtain this.

To enable us to provide you with efficient service, please use the application number and study title in all correspondence with us. If you have any enquiries about this application, or anything else, please do contact us at ethics@aut.ac.nz.

All the very best with your research,

Kate O'Connor

Executive Secretary

Auckland University of Technology Ethics Committee

Cc: stephen.aiello@aut.ac.nz; Bridget Dicker

Appendix B: St John Locality Approval

The below email constitutes a formal locality decision for your study from St John.
Please keep a copy of this email for your records.

Date: 1 December 2016

Study title: Pre-hospital STEMI recognition: An Auckland retrospective study

St John reference: #53

Dear Stephen,

Your research study has undergone a locality review by St John, and I am pleased to inform you that your study is now authorised to go ahead subject to the conditions set out below.

Conditions - general

Progress reports should be submitted to St John annually on 1-May until the conclusion of the project. A link to an online form will be emailed to you when this report is next due for your project.

At the conclusion of the project a final report should be submitted to St John with a synopsis outlining the results, conclusions any recommendations from the study.

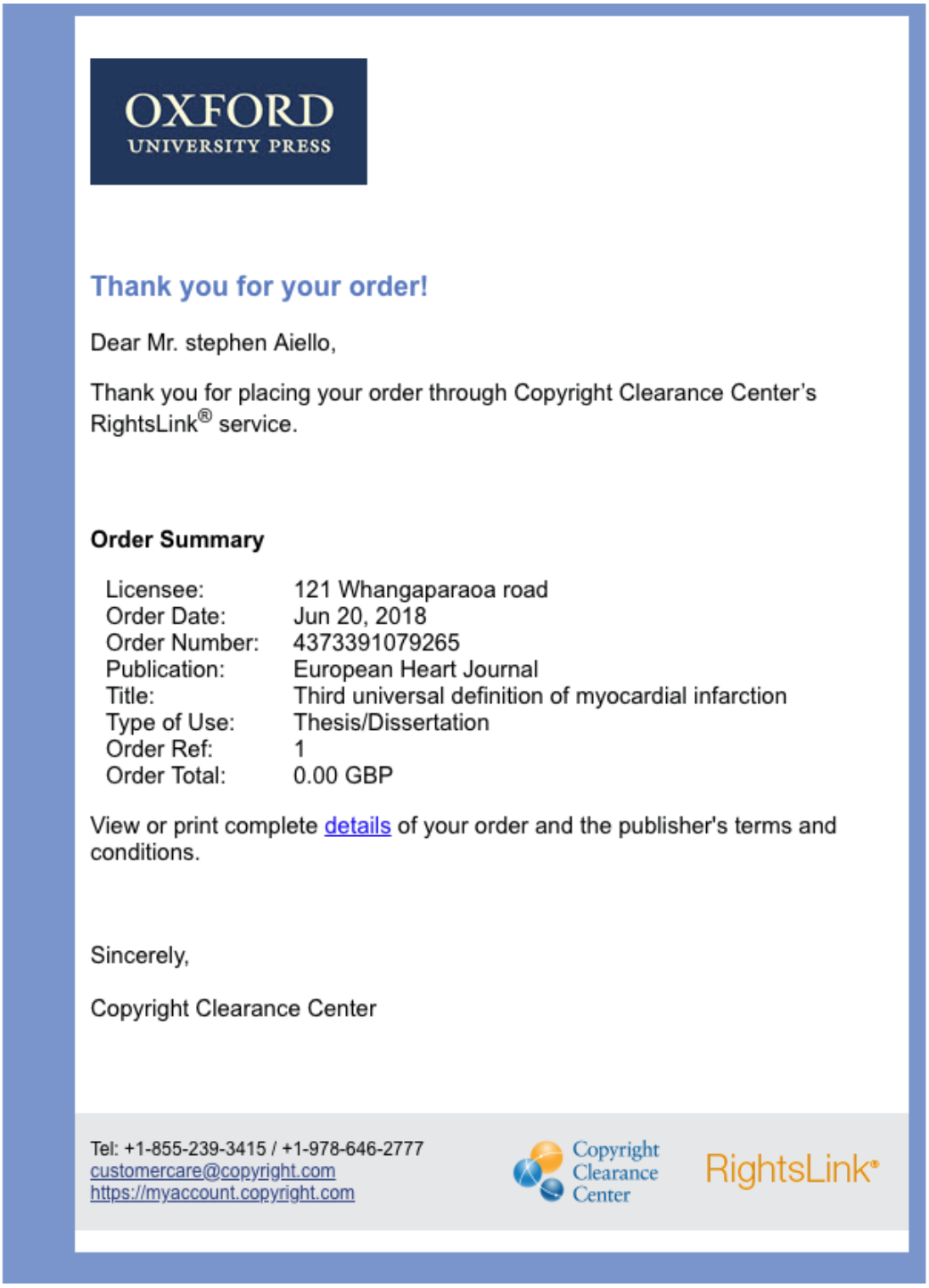
The Principal Investigator is required to complete a copy of the OMF 4.9.7 Research Memorandum of Understanding.

Conditions - project specific
Nil
Yours sincerely

Dr Bridget Dicker, PhD
Clinical Research Fellow
National Headquarters

Bridget Dicker, PhD
Clinical Research Fellow, Northern Region
St John New Zealand | Hato Hone Aotearoa
St John
Here for Life
T +64 9 526 0527 x 8771 | M +64 27 705 2617
E bridget.dicker@stjohn.org.nz
2 Harrison Road I Mt Wellington I Auckland 1060 I New Zealand
Private Bag 14902 I Panmure I Auckland 1741 I New Zealand
www.stjohn.org.nz

Appendix C: Copyright licence: European Heart Journal



OXFORD
UNIVERSITY PRESS

Thank you for your order!

Dear Mr. stephen Aiello,

Thank you for placing your order through Copyright Clearance Center's RightsLink® service.

Order Summary

Licensee:	121 Whangaparaoa road
Order Date:	Jun 20, 2018
Order Number:	4373391079265
Publication:	European Heart Journal
Title:	Third universal definition of myocardial infarction
Type of Use:	Thesis/Dissertation
Order Ref:	1
Order Total:	0.00 GBP

View or print complete details of your order and the publisher's terms and conditions.

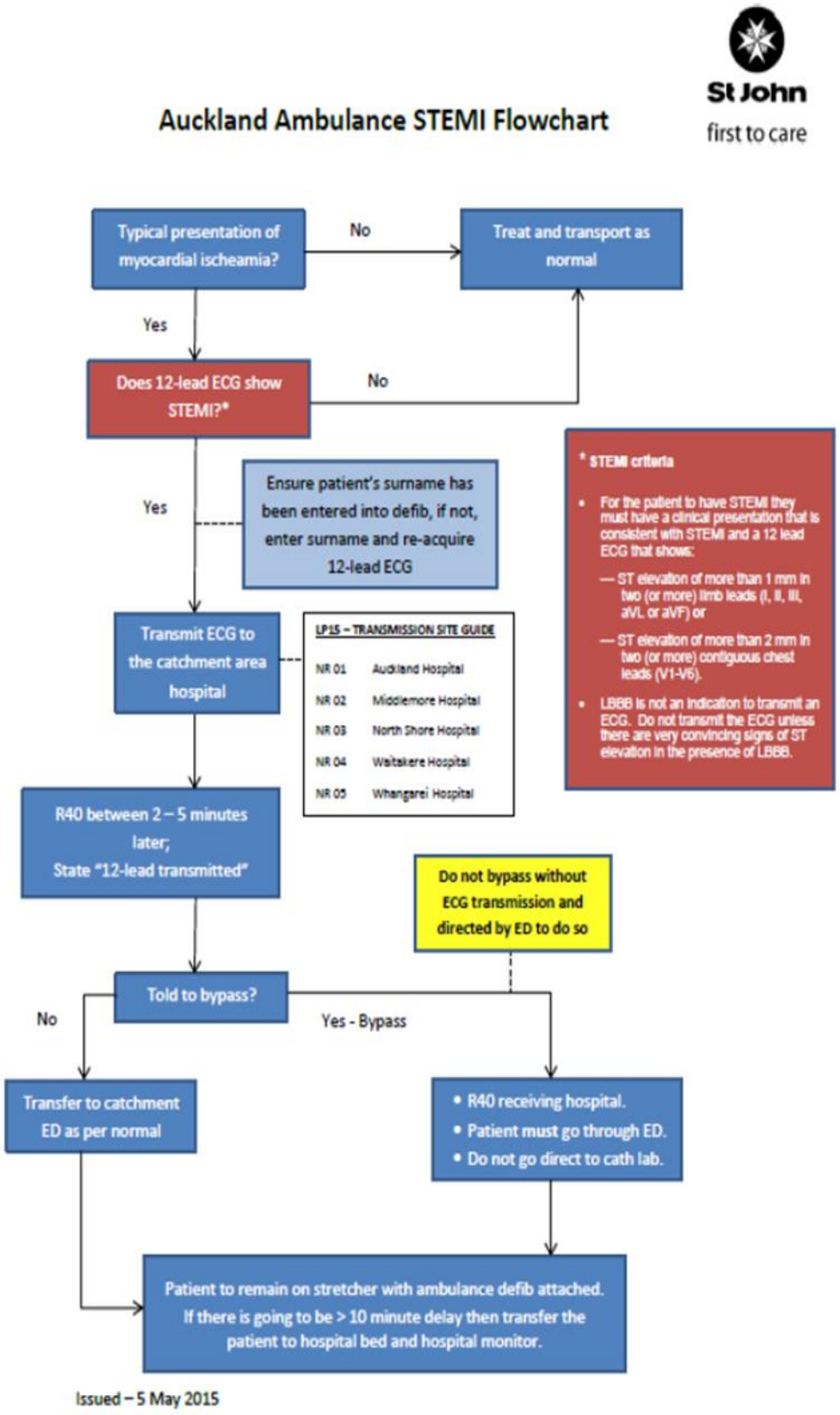
Sincerely,

Copyright Clearance Center

Tel: +1-855-239-3415 / +1-978-646-2777
customercare@copyright.com
https://myaccount.copyright.com

Copyright Clearance Center RightsLink®

Appendix D: St John Ambulance STEMI Flowchart



Permission to reproduce the Auckland Ambulance STEMI flow chart has been granted by St John. Smith, T. Auckland Ambulance STEMI flow chart May 2015. St John. (Appendix E).

Appendix E: Copyright licence: St John Ambulance Service

I am contacting you to seek permission to include the following material within the electronic version of Steven Aiello's MPhil thesis:

Auckland Ambulance STEMI flow chart, as per attached.

The following statement will be included in the thesis, "Permission to reproduce the Auckland Ambulance STEMI flow chart has been granted by St John". The authors will also be cited as per APA guidelines: Smith, T. Auckland Ambulance STEMI flow chart May 2015. St John.

A copy of the the final thesis will be accessible through AUT's online repository (https://tuwhera.aut.ac.nz/open-theses). The repository is non-commercial and openly available to all.

Kind regards,

Bridget

Bridget Dicker, PhD
Head of Clinical Audit and Research, National Headquarters
St John New Zealand | *Hato Hone Aotearoa*
T +64 9 526 0527 x 8771 | M +64 27 705 2617
E bridget.dicker@stjohn.org.nz
2 Harrison Road | Mt Wellington | Auckland 1060 | New Zealand
Private Bag 14902 | Panmure | Auckland 1741 | New Zealand
www.stjohn.org.nz
Please consider the environment before printing this email
St John
Here for Life
St John New Zealand

Appendix F: Quantitative Variables and Source

Variable	Description (Values)	Source
Demographic		
Age	Age in years	ePRF; NRA
Sex	Binary (Male; Female)	ePRF; NRA
Ethnicity	Level 1 NZ census categories (NZ Euro; Māori; Pacifica; Asian; Other)	ePRF
Clinical		
ECG interpretation	STEMI type	ePRF; NRA
Clinical Impression	Working diagnosis	ePRF
Pain Score	Scale 0-10	ePRF
Initial severity status	Scale 0-4	ePRF
Initial chest pain	Binary (Yes; No)	ePRF
final chest pain	Binary (Yes; No)	ePRF
Care quality indicators		
GTN	Binary (Yes; No)	ePRF
Morphine	Binary (Yes; No)	ePRF
Aspirin	Binary (Yes; No)	ePRF
GTN	Binary (Yes; No)	ePRF
IV access	Binary (Yes; No)	ePRF
On scene time	minutes	ePRF
Cardiac arrest	Binary (Yes; No)	ePRF; NRA
Hospital arrival time	Time of day	ePRF; NRA
Hospital management type	PCI; Thrombolysis; none	NRA
Operational		
Hospital name	HOSP 1, HOSP 2, HOSP 3, HOSP 4	ePRF; NRA
Hospital arrival mode	Ambulance; Self-presented	NRA
Incident retrieval location	Home; Public; Healthcare	ePRF
Ambulance officer practice level	ICP; PARA; EMT	ePRF

Note. ICP = Intensive care paramedic; PARA = Paramedic; EMT =emergency medical technician; GTN = glyceryl trinitrate; IV = intravenous; NZ = New Zealand; HOSP = Hospital; NRA = Northern Regional Alliance; ePRF = Electronic Report Form.

Appendix G: Prehospital STEMI Transcript Form

Incident date: _____ Exclusions: (Arrest/CPR/out of region) Y/N

Incident # _____

Receiving Hospital: _____

Sex	
Female	
Male	
Age (years)	
Ethnicity	
NZ European	
Māori	
Asian	
Pacific peoples	
Other	
Incident retrieval location	
Home	
Public	
Healthcare	
Initial clinical status	
One	
Two	
Three	
Four	
Scene time (minutes)	
Ambulance officer practice level	
ICP	
PARA	
EMT	

Initial chest pain	
No	
Yes	
Final chest pain	
No	
Yes	
Morphine	
No	
Yes	
Aspirin	
No	
Yes	
GTN	
No	
Yes	
IV access	
No	
Yes	
STEMI type	
Anterior	
Inferior	
Lateral	
Posterior	
Septal	
Not stated	