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Evaluation of Telephone Cardio-Pulmonary Resuscitation Instructions in Ambulance Clinical Communication Centres – A New Zealand Perspective

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Abstract

Telephone-cardiopulmonary resuscitation (CPR), in which an Emergency Call Handler provides CPR instructions to a caller, has been shown to double the rate of bystander-CPR engagement. The life-saving benefit of the provision of early commencement of CPR is well documented across the literature. Yet, bystander-CPR rates remain relatively low. There is currently no literature in New Zealand which describes or compares the ability of an Emergency Call Handler to accurately recognise out-of-hospital-cardiac-arrest (OHCA) over the phone. Additionally, there are no documented timeframes which measure the time intervals associated with the recognition of OHCA, the commencement of telephone-CPR and the commencement of the first chest compression. The primary aim of this study is to establish the accuracy of Emergency Call Handler recognition of cardiac arrest in New Zealand. The secondary aims of this study are to measure:

(i) the time taken from emergency call pick-up to:

- the recognition of OHCA;
- the commencement of telephone-CPR instructions;
- the commencement of the first chest compression by a bystander.

(ii) bystander-CPR rates.

A retrospective observational study was conducted using data collected from calls placed to the Clinical Communication Service centres in New Zealand during the period 1 April and 30 April 2016 involving OHCA events. After reviewing the audio files of OHCA events, the sensitivity was calculated by measuring the Emergency Call Handlers' ability to accurately recognise OHCA which was then compared to the attending paramedic's findings upon arrival on scene. The median times and interquartile ranges (IQR) associated with the intervals for the Emergency Call Handler to recognise OHCA, commence telephone-CPR instructions and to begin the first chest compression guided by telephone-CPR instructions were recorded. Finally, the rate of bystander CPR was established.

The sensitivity of Emergency Call Handlers' recognition of OHCA was 98%. The median duration of delay from call pick-up to OHCA recognition was 105 seconds (IQR 80-148), the median time taken to the commencement of telephone-CPR instructions

was 146 seconds (IQR 109-212) and the median time from call pick-up to the commencement of the first chest compression was 255 seconds (IQR 201-342). Bystander CPR was in progress when the EMS crew arrived with the patient in 53% of all cases and 70% of cases when the Emergency Call Handler provided telephone CPR instructions.

This study identifies that while the overall rate recognition of OHCA by Emergency Call Handlers in New Zealand is excellent, there is room for improvement in the delay from call pick-up to recognition, initiation of telephone-CPR instructions and the commencement of bystander compressions. All these intervals were longer than American Heart Association guidelines. A higher rate of bystander rate CPR was observed in cases where telephone-CPR instructions were given compared to those where instructions were not supplied.

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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 nor material which, to a substantial extent, has been accepted for the award of any other degree or diploma of a university or other institution of higher learning, except where due acknowledgement is made in the acknowledgements.

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Norm Wilkinson

13 March 2020

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Chapter 1 Introduction

1.1 Out-of-hospital-cardiac arrest

Out-of-hospital cardiac arrest (OHCA) arrest is a sudden unexpected event in which a patient's heart malfunctions, causing it to cease pumping blood around the body, rapidly leading to death. In New Zealand, 1,927 adults over the age of 15 years received emergency care from St John following an OHCA between 1 July 2017 and 30 June 2018 (Dicker, Oliver, & Tunnage, 2018). The majority of cardiac arrest cases occur among adults (97%) with an incidence of 128.8 cases per 100,000 person-years. Internationally, Ambulance Victoria Australia, reported a total of 2,412 OHCA, London Ambulance Service (LAS) in the United Kingdom a total of 4,448 OHCA and King County, in the United States of America reported a total of 775 OHCA over the same time period (Dicker, Oliver, et al., 2018).

Reported survival rates vary internationally. The highest rate of survival at 20% is reported in Washington, United States of America. This reported rate compares to New Zealand survival rates of 13%, reported by St John Ambulance (Dicker, Davey, Smith, & Beck, 2018) and 16% reported by Wellington Free Ambulance Service (Beck et al., 2018). Comparatively, survival rates at 30-days after a cardiac arrest event reported in Australia from three different states were (i) Victoria at 12.6%, (ii) South Australia at 9.8% and (iii)Western Australia's at 9.4% (Beck et al., 2018).

Modifiable pre-hospital factors affecting survival rates include ambulance response times, the provision of bystander cardiopulmonary resuscitation (CPR) and the standard of care provided in the community. Out-of-hospital cardiac arrest (OHCA) survival is reported to be higher in urban areas compared to rural areas. Bystander-CPR is also reported to be higher in urban areas compared to rural areas (Mathiesen, Bjørshol, Kvaløy, & Søreide, 2018).

The Global Resuscitation Alliance was inaugurated in 2015 and developed by the Seattle Resuscitation Academy. The aim of the alliance was to find ways to improve survival for OHCA by exercising best international practices (Nadarajan et al., 2018). The suggested steps include:

i. Institute a cardiac arrest registry
ii. Provision of telephone-CPR with ongoing training
iii. Provide high-performance CPR with ongoing training
iv. The implementation and use of a rapid dispatch system
v. Use defibrillation data to measure resuscitation performance
vi. Initiate an automated external defibrillation programme for first responders.
vii. Use technology to notify bystanders to help with CPR and defibrillation
viii. Mandatory CPR and AED training to be implemented into communities and schools.
ix. Be accountable by publicising annual OHCA reports
x. Facilitate a culture of excellence

The guidelines designed and implemented by the Global Resuscitation Alliance have been adopted by key stakeholders from 26 countries, many of whom contributed to the World Health Organisation's framework of development for Emergency Care Systems (Nadarajan et al., 2018). The study presented in this thesis is aligned to the Global Resuscitation Alliance guidelines and specifically relates to steps ii, iii and iv.

The provision of early telephone-CPR instructions to bystanders by Emergency Call Handlers is becoming standard practice in many countries. This initiative helps to reduce the time delay between onset of OHCA and the provision of CPR (Hardeland et al., 2014; Herlitz, Svensson, Holmberg, Angquist, & Young, 2005; Malta Hansen et al., 2015; Sutter et al., 2015)

1.2 Cardiopulmonary resuscitation

Cardiopulmonary resuscitation is the provision of both external chest compressions and ventilations to generate changes in the intrathoracic pressure in order to move blood to the essential organs during cardiac arrest. Mouth-to-mouth-ventilations (MTMV) is a process whereby a bystander places their mouth over the mouth of a patient in OHCA and then blows air into the patients lungs. This process facilitates the oxygenation of the blood. Cardiopulmonary resuscitation must be initiated immediately to ensure the delivery of oxygen to the brain and other vital organs. Delay to commencement of CPR substantially reduces the patient's chance of survival (Hossmann & Kleihues, 1973). Any delay in the provision of CPR will cause the human brain to die as it can only

survive without oxygen for approximately 3-4 minutes before irreversible death of the neurons occurs. There is limited chance of the brain surviving if the patient has been in OHCA for longer than 8-10 minutes without any form of intervention (Hossmann & Kleihues, 1973).

1.3 Telephone-CPR

The provision of telephone-CPR instructions is a time-critical initiative designed to improve survival rates until paramedics arrive. Telephone-CPR is a sequence of events whereby the 111 Emergency Call Handler upon recognising OHCA provides a set of instructions to guide the bystander to commence CPR. This is achieved by asking a set of predetermined questions to establish that a patient is unconsciousness or has inadequate breathing. This leads to the recognition of OHCA and the subsequent provision of potentially lifesaving telephone-CPR instructions to the caller.

Telephone-CPR instructions have also been shown to increase the rate of bystander-CPR engagement and are associated with improved survival rates at five-years of 14.3% compared to 8.7% ($p = 0.001$) in patients who did not receive bystander-CPR (Geri et al., 2017). Telephone-CPR can increase the frequency of bystander-CPR and, when provided within a short timeframe, is associated with reduced mortality rates in OHCA(Hardeland et al., 2014). Survivability from an OHCA decreases by 3-5% for every minute of delay in the commencement of CPR (Hardeland et al., 2014). Time is therefore of the essence and every minute that passes without the recognition of OHCA reduces the chance of survival.

On recognition of OHCA the Emergency Call Handler will narrate clear, concise CPR instructions to the caller or bystander. A bystander-rescuer is an individual who is willing to assist a patient in OHCA by performing CPR. Not all bystander-rescuers have previously been trained in the process of CPR, so the telephone guidance from a trained Emergency Call Handler must be clear and simple in order to complete the important steps required for CPR.

1.4 The "Chain of Survival"

The "chain of survival" is a framework that was designed by the American Heart Association (AHA) and includes a series of simple illustrated instructional actions that

aim to reduce the time to perform CPR and improve OHCA outcome (Iwami et al., 2009). The provision of early telephone-CPR is one of the significant links in the "chain of survival" which is designed to help reduce mortality rates associated with OHCA. These actions are all required to ensure the best possible outcome in OHCA (Figure 1). They include, (i) early activation of emergency medical services (EMS), (ii) early initiation of CPR, (iii) early use of a defibrillator and (iv) the provision of early advanced life support (ALS). Together, these measures help reduce morbidity and ultimately improve survival rates from OHCA.

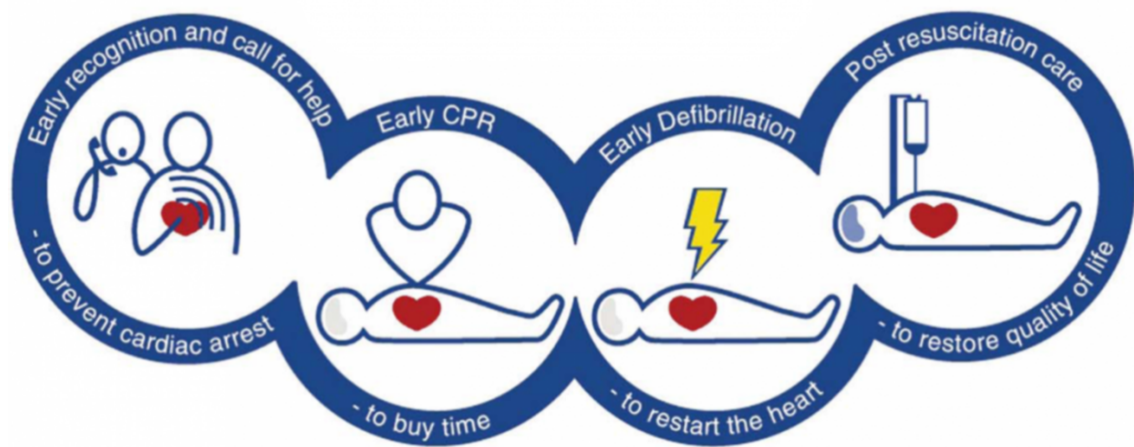

Figure 1 Chain of survival

The early provision of bystander-CPR is but one element within a complex system of important links associated with the "chain of survival". The provision of telephone-CPR instruction is part of the second step of the "chain of survival". An adequately functioning cardiac arrest system involves Emergency Call Handlers', bystanders, emergency medical services and hospital personnel who all contribute to improved survival rates from OHCA.

This thesis will identify vital initiatives and timeframes associated with the first two links in the "chain of survival". These are the accuracy of recognition of OHCA and the time intervals to recognition of OHCA, commencement of telephone-CPR instructions and the first chest compression by a bystander.

1.5 Accuracy of emergency call handler recognition of OHCA

The accuracy in recognising OHCA is of the upmost importance. For the Emergency Call Handler, this is developed by utilising a sequence of questions. Failure or delay in

the recognition of OHCA remains a concern and contributes to poor survival rates (Besnier et al., 2015).

The American Heart Association proposes that recognition of OHCA by Emergency Call Handlers may be helped if specific signs or symptoms among OHCA patients, are reported (Kronick et al., 2015). Some of these signs or symptoms include no chest movement, snoring breathing, inability to wake up, cold and/or blue skin. This recognition can lead to the initiation of the Emergency Call Handler telephone-CPR process. Prior to establishing the location of the emergency, it is reasonable for the Emergency Call Handler to use both the presence of unconsciousness and abnormal breathing to establish OHCA (Moller et al., 2016). It is therefore imperative that Emergency Call Handlers are specifically trained to identify unconsciousness with abnormal breathing, including agonal breathing (Dami et al., 2015).

Agonal breathing, defined as a type of gasping or an abnormal breathing pattern in the presence of unconsciousness, is one of the main factors that leads to failure to recognise OHCA (Brinkrolf et al., 2018). Consequently, agonal breathing is one of the major obstacles leading to the Emergency Call Handler not providing relevant telephone-CPR (Bång, Herlitz, & Martinell, 2003). The most frequent reason reported for Emergency Call handlers' failure to recognise OHCA was the presence of agonal breathing. (Hardeland et al., 2014).

1.6 Time from call pick-up to recognition of OHCA

The time taken to recognise OHCA has become a key performance indicator and is measured quality improvement purposes across many emergency call centres world-wide. To improve the outcome of the patient, it is vital that all Emergency Call Handlers reflect and review their own practice to ensure that recognition of OHCA is achieved in the shortest possible timeframe.

The time taken to recognise OHCA is defined as the time taken from call pick-up to the recognition of cardiac arrest. The American Heart Association recommends that this interval should be less than 60 seconds (American-Heart-Association, n.d).

1.7 Time from call pick-up to CPR instructions and the provision of chest compressions

The early provision of CPR is pivotal in increasing survival from OHCA and lessening the burden of premature death in communities. It has been estimated that CPR can double a patient's chance of survival (Kovic & Lulic, 2011; Kronick et al., 2015). A prolonged time taken to recognise OHCA will have a direct impact on the time taken to commence chest compressions. The American Heart Association that this interval should be less than 180 seconds (American-Heart-Association, n.d).

Caller-related factors may contribute to the delay in recognition of OHCA and subsequently, a delay in the provision of chest compressions. Some of these factors include instances where a caller may be physically unable to move the victim to a hard surface, too emotionally distressed to follow the Emergency Call Handlers' instructions accurately or may have difficulty understanding instructions due to language issues (Langlais et al., 2017). These factors all play a vital role in hindering the commencement of telephone-CPR instructions in OHCA.

1.8 Bystander-CPR rates

The incidence of bystander-CPR rates is highly variable between countries and communities and has been closely linked to the provision of telephone-CPR instructions. For example, OHCA and telephone-CPR has been extensively researched in King County, Seattle. Before the implementation a telephone-CPR system, the rates of bystander-CPR were 30% to 32%. Following the implementation of a telephone-CPR system, these rates increased significantly to 54% to 55% ($p = 0.001$) (Bohm, Vaillancourt, Charette, Dunford, & Castrén, 2011). Similarly, in Finland, when OHCA was recognised by the Emergency Call Handler, bystander-CPR rates increased to 71.3% (Hiltunen, Silfvast, Jäntti, Kuisma, & Kurola, 2015). Bystander-CPR rates reported on in Japan found that bystander-CPR increased from 42% to 62% ($p = 0.001$) after the introduction of telephone-CPR instructions (Tanaka, Taniguchi, Wato, Yoshida, & Inaba, 2012). The American Heart Association notes that bystander-CPR rates in the United States of America continue to be highly variable and range from as low as 10% to as high as 65% (Kronick et al., 2015).

Bystander-CPR rates in New Zealand between 2016 and 2017 were found to be 72% and 74% respectively (Dicker, Davey, et al., 2018; Dicker, Howie, & Tunnage, 2017).

The variability of bystander-CPR rates across the literature may be attributed to a several factors. These include the bystander's unwillingness to assist due to a lack of understanding of the signs and symptoms of OHCA, language barriers, risk of infections or a fear performing chest compressions (Alfsen, Møller, Egerod, & Lippert, 2015; Langlais et al., 2017).

Bystander-CPR rates have been reported to double (22% to 49%) when telephone-CPR instructions were provided (Ng, Leong, & Ong, 2017), the rates of bystander-CPR however continue to remain relatively low. Studies have suggest that the introduction of telephone-CPR increased the frequency of bystander-CPR engagement, which in turn positively affected neurological outcome and survival rates (Fujie, Nakata, Yasuda, Mizutani, & Hashimoto, 2014; Tanaka et al., 2012).

1.9 Emergency call handler compliance with dispatch tools

The fourth recommendation suggested by the Global Resuscitation Alliance was the implementation and use of a rapid dispatch system. Two such tools which are currently used in Clinical Control Service Centres around the world include the ProQA™ Medical Priority Dispatch System (MPDS) (previously known as the Advanced Medical Priority Dispatch System or AMPDS) and the Criteria-Based Dispatch (CBD) tool. These tools are designed to guide Emergency Call Handlers when dealing with emergency telephone calls and to ensure that emergency personal and resources are dispatched to emergency cases appropriately.

1.9.1 ProQA™ Ambulance Medical Priority Dispatch System

The ProQA™ MPDS is a tool widely used by Clinical Communication Service (CCS) centres around the world. The tool is designed for multiple purposes which include priority dispatching, recognition of life-threatening medical emergencies, standardise the process of Emergency Call Handler questioning while optimising and supporting safe and efficient patient care (Cady, 2014). The ProQA™ MPDS protocol uses a system of inquiry and symptom recognition that enables the Emergency Call Handler to prioritise ambulance response according to pre-defined response algorithms. The design of the ProQA™ MPDS facilitates improved clinical accuracy, efficiency and

professionalism along with minimisation of potential mistakes. When the ProQA™ AMPDS was introduced into the London Ambulance Service in 2003, the accuracy of Emergency Call Handlers recognition of patients in cardiac arrest increased from 15% to 50% (Heward, Damiani, & Hartley-Sharpe, 2004). With appropriate training and experience, the ProQA™ MPDS tool has proven to be an invaluable asset in the early recognition of OHCA and facilitates the provision of early life-saving telephone-CPR instructions. The ProQA™ MPDS helps to eliminate potential Emergency Call Handler bias, errors and gaps through the use of scripted pre-arrival interrogations and instructions.

The ProQA™ MPDS optimises the use of the limited EMS resources available for dispatch. The ability to safely prioritise ambulance responses ensures the availability of these resources for medical conditions that require a critical response with the highest clinical capability.

The ProQA™ MPDS prioritises the actions of the Emergency Call Handlers and bystanders to ensure that life-threatening conditions are identified and responded to immediately. The bystander or caller is the first person acting on behalf of the patient who has the shortest response time to provide supportive care to the patient. The ability of the Emergency Call Handler to recognise potential life-threats and provide life-saving instructions is dependent on the recognition of a life-threatening condition such as OHCA. This is initially achieved through case entry questions.

Case entry questions are designed to identify whether or not a life-threatening condition exists and where the response is needed. The Emergency Call Handler is directed by the ProQA™ MPDS to first perform an initial assessment, similar to that of a paramedic in the field, through "Case Entry" questions. The importance of establishing whether or not the caller is conscious and breathing offers the first opportunity to begin telephone directed CPR instructions (Cady, 2014).

While the ProQA™ MPDS tool has been shown to improve OHCA recognition, there is still a significant delay in the recognition of OHCA and the provision of telephone-CPR instructions. Prolonged delays in recognition and the provision of telephone-CPR is associated with the use of ProQA™ MPDS tool (Moller et al., 2016).

1.9.2 Criteria based dispatch

Criteria Based Dispatch® (CBD) is an emergency medical dispatch triage program that is based on patient signs and symptoms collected by Emergency Call Handlers (King County Emergency Medical Services Division, 2010). Assessing the patients' initial signs and symptoms at the time of the call allows for the review of dispatch accuracy.

Particular questions are defined by protocols or an algorithm which is used during patient interview and triage. Guidelines provide direction and assist in decision-making, but without structuring the course of action so that it becomes restrictive, or limits the dispatchers' ability to gather crucial information and act quickly. In CBD, Emergency Call Handlers are assisted by guidelines to help identify the most appropriate resource to send to a medical emergency. The aim of using this software is to establish a focus on the critical systems and to identify patients that are facing a health crisis quickly (King County Emergency Medical Services Division, 2010).

1.10 Emergency Medical Services in New Zealand

The St John ambulance service in New Zealand provides pre-hospital emergency medical care cover to a population in the region of 4 million people (Dicker, Oliver, et al., 2018). The St John ambulance service extends over the majority of the country covering approximately 262,000 square kilometres. Most OHCA events in New Zealand are attended by St John Ambulance, which serves approximately 90% of New Zealand’s population and 97% of the geographic area. Between 1 October 2013 to 30 September 2015, a total of 7,996 OHCAs were attended by St John of which 3,862 (48%) had resuscitation attempted. Bystander-CPR rates in New Zealand at the time of this research between 2016 was reported to be 72% with a survival rate of 12% (Dicker et al., 2017).

In New Zealand, in the event of an OHCA, bystanders or healthcare providers call the emergency services via the telephone 111 emergency system. Health emergencies, such as cardiac arrest are transferred by the 111 operator to a CCS centre either in Christchurch, Wellington or Auckland. Emergency Call Handlers in New Zealand use the ProQA™ MPDS version 12, as a prescriptive tool to recognise cardiac arrest and subsequently guide the caller through how to perform CPR. Telephone-CPR

instructions to bystanders were first introduced into the CCS centres in New Zealand in 2002 (Dicker, Davey, et al., 2018; Dicker et al., 2017).

While many countries report OHCA survival rates, there is a scarcity of literature describing the recognition of OHCA by Emergency Call Handlers in New Zealand. The ability for an Emergency Call Handler to recognise OHCA underpins the process of telephone-CPR. Understanding the process of the early recognition of OHCA and the provision of life-saving instructions may improve outcomes after cardiac arrest. As previously described, the Global Resuscitation Alliance has identified ten steps to improve survival from OHCA through best practice. Three of these suggested best practices are explored in this study. These practices, are the provision of both telephone-CPR and high-performance CPR and the implementation and use of a rapid dispatch system.

The primary aim of this study is to establish the accuracy of Emergency Call Handler recognition of cardiac arrest. The secondary aims are to measure:

(i) the times taken from emergency call pick-up to:

- the recognition of Out of-Hospital-Cardiac-Arrest (OHCA);
- the commencement of telephone-CPR instructions;
- the commencement of the first chest compression by a bystander;

(ii) bystander-CPR rates.

1.11 Structure of the thesis

This thesis is comprised of six chapters. The structure of the thesis is shown in *Figure 2*.

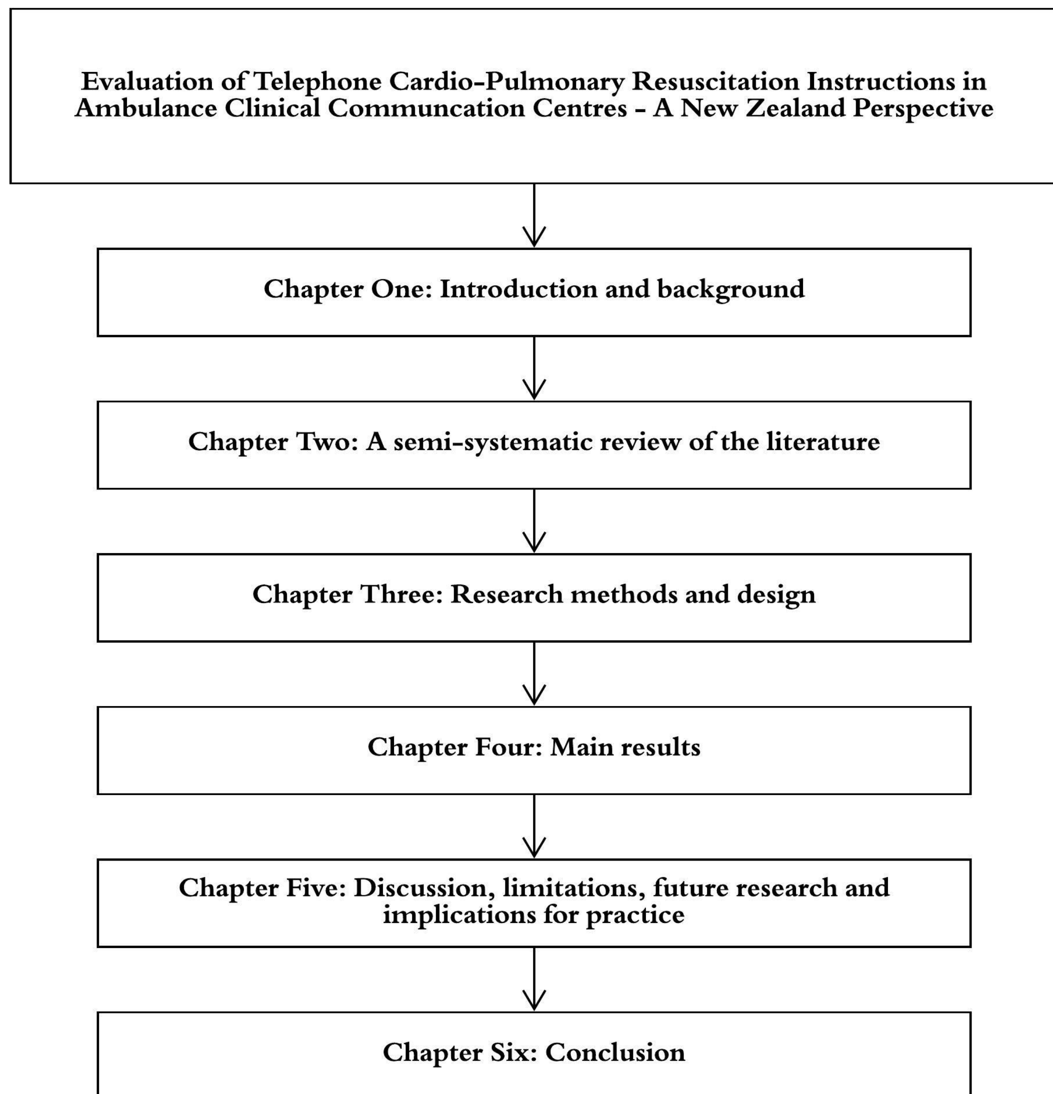

Figure 2 Structure of the thesis

Chapter One has introduced telephone-CPR guided by an Emergency Call Handler and insight into the ambulance system in New Zealand. It highlighted the significance of early recognition of cardiac arrest and the timely intervention of telephone-CPR instructions. Discussion included the importance of bystander-CPR and the vital role that early CPR has within the "chain of survival" on survival rates. The study aims were presented. The findings of this study will provide insight into the accuracy of OHCA recognition in New Zealand and contribute to international findings. Furthermore, the

speed at which recognition is achieved, and subsequent chest compressions commenced, and bystander-CPR rates will also be measured.

Chapter Two is a semi-systematic review of the literature that focuses on determining the sensitivity of the recognition of OHCA by Emergency Call Handlers. The timeframes associated with each stage of telephone-CPR instruction by Emergency Call Handlers are reviewed. The review aims to identify the frequency of bystander-CPR when telephone-CPR instructions are provided. Similarities and differences between the studies' methods and findings are described. This chapter concludes with the limitations of the literature review and a summary of the findings.

Chapter Three describes the methods of the study. This chapter commences by restating the research aims and then provides a detailed description of the methods used within the study. The study design, setting, population, variables and data sources are explained first. A discussion regarding the handling of the quantitative variables and presentation of the statistical methods is described. This chapter is structured to follow the Strengthening the Reporting of Observational Studies in Epidemiology (STROBE) guidelines (Vandenbroucke et al., 2014). These guidelines were constructed specially to improve the clarity and consistency of reporting.

Chapter Four presents the results of this study. This provides a New Zealand perspective by reporting the sensitivity of cardiac arrest recognition rates by the Emergency Call Handler compared to the attending paramedic and quantifies the three critical time intervals. Specifically, the time taken from call pick-up to recognition of OHCA, time to the commencement of telephone-CPR instructions and the time taken for the bystander to commence the first chest compression. Additionally bystander-CPR rates are reported.

Chapter Five reviews the findings identified in the current study. These findings are discussed in relation to the findings identified in the reviewed literature. The limitations of the current study are also reflected on. Suggestions for future research opportunities are identified and discussed. The implications of the findings of this enquiry on practice within the New Zealand EMS sector are also addressed.

Chapter Six provides the conclusion to the study.

Accompanying materials which support the discussion are included as appendices. A glossary of terms is included before the Reference List to assist with standard abbreviations used within the text.

Chapter 2 A review of the literature

2.1 Introduction

A semi-systematic literature review of key topics was undertaken. The accuracy of OHCA recognition by Emergency Call Handlers/Dispatchers, the time intervals from call pick-up to the recognition of OHCA, commencement of telephone-CPR instructions and the commencement of the first chest compression, and bystander-CPR rates were explored. Among the reviewed literature, the ProQA™ Ambulance Medical Priority Dispatch (MPDS) and Criteria Based Dispatch® (CBD) system software were the two most commonly used dispatch software platforms used while providing telephone-CPR instructions. Some of the reviewed studies exercised no formal use of a dispatch software to guide their recognition of OHCA or telephone-CPR initiatives while others utilised an in-house dispatch system to assist in their initiatives. This chapter describes the methods used to identify relevant material and presents a review of the literature. The results are guided by the Preferred Reporting Items for Systematic Review and Meta-Analysis Protocol (PRISMA-P) checklist.

2.2 Methods of the literature review

The Electronic databases Cochrane, Medline, CINAHL, Scopus (OVID and EBSCO) were searched using the key terms “Emergency Call Hander” and “CPR OR cardio-pulmonary resuscitation” AND “Telephone-CPR” AND “time to compressions” AND “bystander-CPR”. Articles describing telephone-CPR instructions by Emergency Call Handlers were eligible for inclusion. Limits included language (English), no full text journal articles and date of publication (2009-2019). The date range was selected so that the data collection period was deemed to be the most relevant over the last 10 years. Reference lists of articles selected for review were examined to identify any additional potentially relevant articles that were not identified by the main search strategy. The search and article selection process are addressed below in Figure 3.

The PRISMA protocol was used to ensure that the literature review met all the criteria for a systematic literature review (Moher et al., 2015). The PRISMA-P checklist was used with the majority of the criteria being met. Protocol registration was not used as no review protocol exists. As not all the PRIMA-P criteria were met, this literature review cannot be deemed to be a systematic literature review but rather a semi-systematic

literature review. All papers meeting inclusion criteria for the literature review were classified according to quality based on the AHA level of evidence method (Kronick et al., 2015).

2.3 Literature review results

The search identified a total of 298 potentially relevant papers (Figure 3). After exclusion based on date, English language, full text and duplicates a total of 13 articles met the criteria. After reviewing the abstracts, a further two articles were excluded as they did not discuss “telephone-CPR”, leaving 11 articles for final review. There were no randomised controlled trials or meta-analyses found within the review that investigated telephone-CPR instructions. All eleven studies selected for review were quality level C-LD according to the AHA method (Kronick et al., 2015).

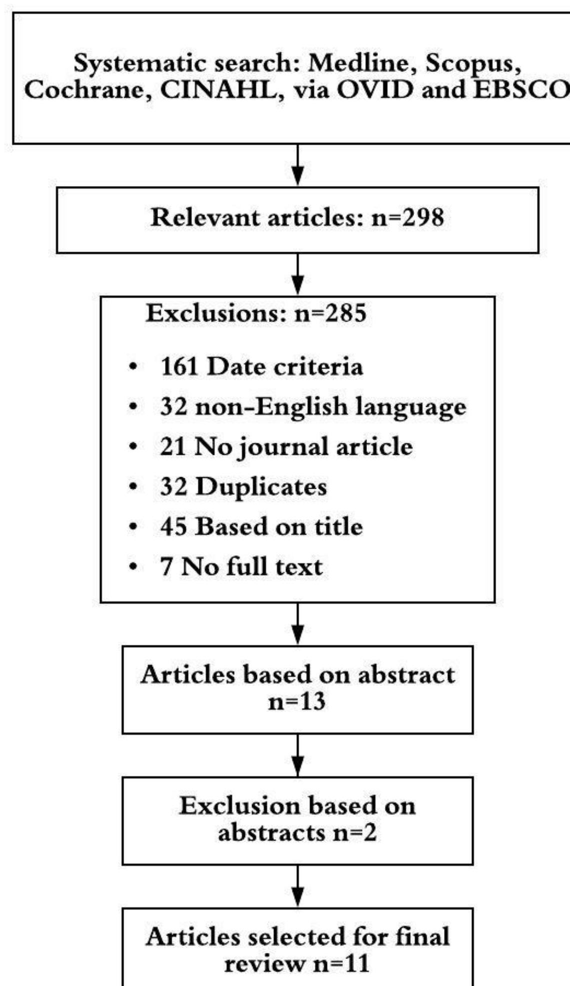

Figure 3 Literature selection process

Table 1 presents a summary of the reviewed literature. For each study, the primary author, location where the respective research was conducted, enrolment dates and the sample size is identified.

Table 1 *Full paper review articles*

Authors	**Country**	**Enrolment dates**	**Sample size (*n*)**
Dami, Fuchs, Praz and Vader (2010)	Switzerland	July 2008 - June 2009	497
Dami et al. (2015)	Switzerland	Jan 2011 - Dec 2013	1697
Deakin et al. (2010)	United Kingdom	April 2007 - March 2008	42
Hardeland et al. (2014)	Norway	May 2010 - April 2011	414
Lewis, Stubbs, and Eisenberg (2013)	United States of America	Jan 2011 - Dec 2011	476
Moller et al. (2016)	Sweden	July 2013 - Dec 2013	697
Nuno et al. (2017)	United States of America	Oct 2010 - Dec 2013	202
Oman and Bury (2016)	Ireland	Jan 2011 - Dec 2012	202
Stipulante et al. (2014)	Belgium	Nov 2010 - Jan 2011	569
Vaillancourt et el. (2015)	Canada	Jan 2008 - Oct 2009	2260
Van Vleet and Hubble (2012)	United States of America	Oct 2005 - March 2010	778

2.3.1 Accuracy of emergency call handler recognition of OHCA

Accuracy is commonly measured according to sensitivity and specificity (Hennekens & Buring, 1987). The sensitivity of Emergency Call Handlers' recognition of OHCA was reported in ten studies (Table 2). Among these studies, the reported sensitivity ranged from a low of 66% (Vaillancourt et al., 2015) to a high of 90% (Nuno et al., 2017). The sensitivity scores of the Emergency Call Handler recognition were generally spread but there was some consistency in sensitivity scores in the research where the ProQA™ MPDS/CBD system was used, most of which ranged from between 80% to 86%. The only study which was not within the range of between 80% to 86% while using the ProQA™ MPDS/CBD system was conducted in the United Kingdom where a sensitivity of 73% was achieved (Deakin, Evans, & King, 2010). There were a number of possible reasons for this variation. The sensitivity range across the literature may be attributable to varying study methodologies. For example, sample sizes ranged from 42 (Deakin et al., 2010) to 3,398 participants (Nuno et al., 2017). Furthermore, not all the

studies included in the review utilised the ProQA™ MPDS or the CBD system, and Emergency Call Handler experience and training also varied across the literature.

The American Heart Association (AHA) guidelines recommend that Emergency Call Handlers be able to recognise 95% of the OHCA and that 75% of recognised OHCA receive telephone-CPR (Kronick et al., 2015). It is evident through this review that the ProQA™ MPDS studies fall well short of the suggested 95 % sensitivity rate mentioned above. The reviewed studies do report similar and comparable findings in relation to the sensitivity of OHCA.

Four of the reviewed studies did not have a ProQA™ MPDS or CBD system in place (Dami, Fuchs, Praz, & Vader, 2010; Nuno et al., 2017; Stipulante et al., 2014; C. Vaillancourt et al., 2015). These four studies had a sensitivity score ranging from 66% to 90%. The lowest reported sensitivity score of 66% was reported by Vaillancourt et al. (2015) and the highest of 90% by King County Emergency Medical Services in the USA (Nuno et al., 2017). The authors, unfortunately, do not describe the dispatch tool used to achieve their high sensitivity result.

Table 2 *Published data on OHCA Sensitivity, Specificity, Time to OHCA Recognition, Time to First Compression, Bystander-CPR Rates and Use of the MPDS/CBD System*

Author	**Sensitivity OHCA recognition**	**Specificity OHCA recognition**	**Time to OHCA recognition**	**Time to First Compression**	**Bystander-CPR Rates**	**Use of MPDS/CBD System**
Dami et al. (2010)	69%	-	-	-	69%	No
Dami et al. (2015)	84%		60s	220s	38.4%	Yes
Deakin, Evans & King (2010)	73%	99.7%	180s	280s	68.4%	Yes
Hardeland et al. (2014)	82%		-	240s	65 % & 31%	Yes
Lewis et al. (2013)	80%	-	75s	176s	62%	Yes
Moller et al. (2016)	86%		-	-	62.7%	Yes
Nuno et al. (2017)	90%	-	87s	174s	59%	No
Oman & Bury (2016)	70%		60s	328s	73%	Yes
Stipulante et al. (2014)	82%	-	-	168s	9.8% & 22.5%	No
Vaillancourt et al. (2015)	66%	32.3%	-	-	44%	No
Van Vleet and Hubble (2012)	-	-	240s	240s	81%	Yes

**Note:* S = Seconds

Sensitivity results were reported across six studies which had a ProQA™ MPDS/CBD system in place and demonstrated a sensitivity score ranging from 70% to 86% (Table 2). The two lowest sensitivity scores of 70% and 73% were reported in Ireland and the United Kingdom respectively (Deakin, Evans, & King, 2012; Oman & Bury, 2016). Both of these studies were conducted in EMS systems that utilised a ProQA™ MPDS/CBD tool. The sensitivity score of 73% reported by Deakin et al. (2012) occurred in a paediatric only study with a sample of 42 children. The ProQA™ MPDS suggests that two ventilations be provided to all children prior the commencement of compressions. While this action is unlikely to impact on the recognition of OHCA, it may increase the time taken by Emergency Call Handlers to identify the absence of breathing thereby delaying the recognition of OHCA and commencement of chest compressions. The observed low sensitivity may also be attributed to the study being underpowered with a small study sample. Unfortunately, our literature review did not identify any other study within the reviewed cohort which only used children as the sample studied. A comparison could therefore not be conducted. The authors of the Irish study did not present a reason for the lower sensitivity result observed within their study (Oman & Bury, 2016).

A direct comparison was drawn between the sensitivity of OHCA recognition findings across both the ProQA™ MPDS and CBD systems in one study (Hardeland et al., 2014). The authors reported a marginal difference in the sensitivity to the recognition of OHCA: 82% and 77% respectively (p = 0.42). The difference between the two systems could be attributed to education, workplace dynamics, experience and proficiency of the dispatchers across the two systems.

In the non-ProQA™ MPDS/CBD system study conducted by Stipulante et al. (2014), the authors looked at the sensitivity to the recognition of OHCA pre and post implementation of a modified dispatch system. The authors reported a reduced sensitivity of 74.8% after the implementation of the modified tool when compared to the pre-implementation model of 81.5% (p = 0.05). The authors could not directly determine causation for this finding.

Specificity was only reported on in two studies (Deakin et al., 2010; C. Vaillancourt et al., 2015). The specificity of recognition of OHCA ranged from 32.3% to 99.7%. The reason for this varied specificity score range could be attributed to differing methodologies and sample sizes. The modest specificity score of 32.3% reported by

Vaillancourt et al. (2015) was a multi-centre prospective cohort study which had a sample size of 2260 participants. By contrast, Deakin et al. (2010) report a specificity score of 99.7% utilising a retrospective observational methodology involving only 42 participants who were all reported to be paediatric patients.

These comparisons demonstrate that the ProQA™ MPDS/CBD system may provide a form of consistency around the sensitivity in recognition of OHCA and their ability to help Emergency Call Handlers recognise OHCA.

2.3.2 Time from call pick-up to recognition of OHCA

The time taken to identify OHCA is the time from call pick-up to the recognition of cardiac arrest. This measure has become a key performance indicator across emergency call centres worldwide. The literature review identified several timeframes across many countries. These timeframes were measured and reported on in services that utilise non-ProQA™ MPDS and ProQA™ MPDS/CBD systems and are summarised in Table 2.

The American Heart Association (AHA) guidelines recommend that median time to recognition of cardiac arrest should not exceed 60 seconds (Kronick et al., 2015). The reviewed studies do report similar and comparable findings in relation to the time taken to the recognition of OHCA.

Six studies reported the time taken for cardiac arrest to be recognised (Table 2) (Dami et al., 2015; Deakin et al., 2010; Lewis et al., 2013; Nuno et al., 2017; Oman & Bury, 2016; Van Vleet & Hubble, 2012). Only one of the six studies did not have a ProQA™ MPDS/CBD system in place (Nuno et al., 2017). The time taken to recognise OHCA within these five studies ranged between 60 seconds and 240 seconds. These inconsistencies may be attributed to training, the experience of staff or compliance issues within the respective system (Hardeland et al., 2017; Rea, 2016).

The single study that did not use a ProQA™ MPDS/CBD system demonstrated a more favourable time to recognition of OHCA of 87 seconds (Nuno et al., 2017). By contrast, this timeframe is significantly better than those timeframes reported within four of the five ProQA™ MPDS /CBD system studies (Deakin et al., 2010; Hardeland et al., 2014; Lewis et al., 2013; Oman & Bury, 2016). The impact of the ProQA™ MPDS/CBD system could not be concluded from these results.

It is essential to acknowledge that the longer it takes for an Emergency Call Handler to recognise OHCA, the longer it will take for telephone-CPR instructions to commence. It has been suggested that for every minute of delay in the provision of CPR, a victim's chances of survival are reduced by 7% to 10% when there is no CPR attempted (Van Vleet & Hubble, 2012). One common finding which has been reported to hinder the Emergency Call Handlers' ability to recognise OHCA across all the reviewed studies is the presence of agonal breathing. Agonal breathing is described as the most critical reason for not recognising OHCA (Hardeland et al., 2014).

2.3.3 Time from call pick-up to commence telephone-CPR instructions

The time taken to commence telephone-CPR instructions is defined as the time taken from call pick-up to the commencement of telephone-CPR instructions. The American Heart Association recommend that this timeframe be achieved in less than 120 seconds (American-Heart-Association, n.d). This interval from call pick-up until commencement of telephone-CPR instructions was not reported by any of the reviewed studies. Only the time from call pick-up to the provision of the first chest compression has been reported, as discussed in the next section. The American Heart Association describes the Emergency Call Handler and the bystander performing bystander-CPR as a team. The willingness of the bystander and the expertise of the Emergency Call Handler synergise to facilitate OHCA recognition, initiation of telephone-CPR and thereby increase bystander-CPR rates (Kronick et al., 2015).

The time taken to question the caller is of great interest when considering the interval from call pick-up to initiation of telephone CPR instructions. In one study, an extended time taken to commence the first chest compression of 328 seconds was observed (Oman & Bury, 2016). The authors hypothesise that the time taken to complete the standard 21 questions along with caller compliance, repeated questioning, and ambient noise added additional time to the process of establishing the presence of OHCA. In addition, half of the time taken during a call was taken up with patient assessment, including breathing checks.

There are a number of physical barriers that contribute to the delay to commencement of the first compression by a bystander. For example, the rescuer may be unable to move the victim to a hard surface because they are found on a bed, they are too heavy, or they are found in an awkward position. These physical barriers may extend the time taken to initiate telephone-CPR instruction and subsequently the first chest compression

(Eisenberg, 2017). Consequently, these barriers may also affect the rates of bystander-CPR engagement.

Bystander-CPR rates were reported by all of the reviewed studies. Several variables were found which may impede the initiation of bystander-CPR. The authors suggest that these barriers could be overcome by community education efforts, role-playing and concise yet practical instructions to ensure early commencement of bystander-CPR. This is discussed further in section 2.4.5 below.

2.3.4 Time from call pick-up to commence the first chest compression

The time taken to commence the first chest compression is defined as the time interval from call pick-up until the first compression is provided to the cardiac arrest victim (American-Heart-Association, n.d). The time to commencement of the first compression was reported by eight of the reviewed studies (Table 2) (Dami et al., 2015; Deakin et al., 2010; Hardeland et al., 2014; Lewis et al., 2013; Nuno et al., 2017; Oman & Bury, 2016; Stipulante et al., 2014; Van Vleet & Hubble, 2012). The shortest time of 174 seconds was reported by Nuno et al. (2017), the longest time reported time was 328 seconds ((Oman & Bury, 2016). Three of the eights studies to report on the time to first compression fell within the AHA recommendation of 180 seconds (Lewis et al., 2013; Nuno et al., 2017; Stipulante et al., 2014).

Among the six studies using the ProQA™ MPDS or CBD system, the delay from call pick-up to commencement of the first compression ranged from 176 seconds to 328 seconds (Dami et al., 2015; Deakin et al., 2010; Hardeland et al., 2014; Lewis et al., 2013; Oman & Bury, 2016; Van Vleet & Hubble, 2012). The two non-ProQA™ MPDS/CBD system studies reported the times taken from call pick-up to the commencement of the first compression at 168 seconds and 174 seconds (Nuno et al., 2017; Stipulante et al., 2014).

One study made a direct comparison of three different versions of the ProQA™ MPDS (v11.2, v11.3 & v12.0) (Van Vleet & Hubble, 2012). In a review of the ProQA™ MPDS version changes, they compared the time taken to commence the first chest compression across the three versions of the ProQA™ MPDS. The authors found no significant difference in the time taken to begin the first chest compression across the three versions. The reported times across the three versions were 240 seconds, 244 seconds and 248 seconds (p= 0.08) respectively. The authors also compared the time

taken to commence the first chest compression with and without MTMV. When MTMV was offered as part of the instructions, the mean time taken to start the first chest compression increased substantially to 315 seconds. The authors also found that there was no correlation between Emergency Call Handler experience and time taken to commence the first chest compression ($p = 0.71$). The study, however, demonstrated that novice Emergency Call Handlers did slightly better in the time taken to commence the first chest compression category with 240 seconds compared to experienced Emergency Call Handlers with 247 seconds. The authors further hypothesise that compression-only CPR increased the frequency of bystander-CPR being initiated and reduced the time taken to commence the first chest compression.

Language barriers were identified to be a potential reason for delay in both recognition and time to commence the first chest compression in OHCA. Research conducted in a non-ProQA™ MPDS/CBD system found that the time taken to commence the first chest compression was 174 seconds with no language barrier. However, this time was substantially extended to 291seconds seconds when a language barrier (Spanish) was present ($p = 0.001$) (Nuno et al., 2017).

Another reason identified which may protract the time taken to commence the first chest compression is whether a dispatch software tool had been used. After the implementation of a modified dispatch tool in Belgium, it was found that before implementation of the tool the time taken to commence the first chest compression was 253 seconds. Post-implementation of the modified tool demonstrated an improved time taken to commence the first chest compression of 168 seconds ($p = 0.001$) (Stipulante et al., 2014). The type of dispatch software used during this period was unfortunately not stated in this study.

The two dispatch systems, ProQA™ MPDS and CBD, have also been directly compared on their performance.. The times taken to commence the first chest compression were 258 seconds and 222 seconds, respectively (Hardeland et al., 2014). It was suggested that the CBD system commenced the first chest compression 36 seconds faster than the ProQA™ MPDS which was significant (p=0.05). Another study however contradicts this finding and suggests that the CBD system tool does not differ from the ProQA™ MPDS. The research found that the time taken to commence the first chest compression was 220 seconds across both the ProQA™ MPDS and the CBD systems (Dami et al., 2015)

Of the seven ProQA™ MPDS/CBD systems studies reviewed, four of the studies presented very similar times taken to commence the first chest compression (Dami et al., 2015; Deakin et al., 2010; Hardeland et al., 2014; Van Vleet & Hubble, 2012). The longest reported time taken to commence the first chest compression was 328 seconds (Oman & Bury, 2016). The authors further suggest that a delay in the initiation of chest compressions in OHCA was primarily due to the lengthy questioning, whilst the ProQA™ MPDS tried to establish the location and condition of the patient.

The shortest time taken to commence the first chest compression reported was 176 seconds while using the ProQA™ MPDS (Lewis et al., 2013). This timeframe is significantly less than the other published ProQA™ MPDS studies. One possible explanation for this is that no MTMV was advised and that compression-only CPR was directed via telephone-CPR. The findings of this review supported substantially longer times to initiate the first chest compression when a ProQA™ MPDS or CBD system is used compared to no dispatch system.

The time taken to commence the first chest compression has a significant influence on the outcome of any patient suffering from OHCA. Several reasons for the delay in the provision of the first chest compression have been hypothesised across the reviewed literature. The reasons include delays due to extended questioning, extended time on breathing checks due to agonal breathing, language barriers and the use of a ProQA™ MPDS or CBD system dispatch tool. Several variations to the dispatch system have been suggested over the years to reduce the time taken to commence the first chest compression. All the reviewed articles suggest that telephone-CPR instruction and the time taken to commence the first chest compression must be reduced by simplifying the questions, reducing any MTMV and moving to chest compression-only CPR instructions (Dami et al., 2015; Deakin et al., 2010; Hardeland et al., 2014; Lewis et al., 2013; Van Vleet & Hubble, 2012)

2.3.5 Bystander-CPR rates

Bystander-CPR is one of the important links associated with the “chain of survival”. This link in the chain plays a significant role in increasing survival rates from OHCA. Telephone-CPR instructions are a vital step in the “chain of survival”. Telephone-CPR instructions are intended to increase bystander-CPR engagement. It has been established that the failure to recognise OHCA will cause a delay or even a non-provision of telephone-CPR instructions. Much of the literature hypothesises that the initiation of

telephone-CPR increases bystander-CPR rates, this was not evident in all the literature reviewed, Figure 4.

Bystander-CPR rates were investigated and reported across all eleven reviewed studies. Bystander-CPR rates ranged between 22.5% to 81%. The bystander-CPR rates achieved while using the ProQA™ MPDS/CBD systems ranged between 38.4% and 81% (Dami et al., 2015; Deakin et al., 2010; Hardeland et al., 2014; Lewis et al., 2013; Moller et al., 2016; Oman & Bury, 2016; Van Vleet & Hubble, 2012). The bystander-CPR rates achieved when no ProQA™ MPDS/CBD system was used ranged between 22.5% and 69% (Dami, Fuchs, et al., 2010; Nuno et al., 2017; Stipulante et al., 2014; Vaillancourt et al., 2015).

One study directly comparing the ProQA™ MPDS and the CBD system reported bystander-CPR rates of 61% and 31% ($p = 0.001$) respectively (Hardeland et al., 2014). These results were supported by a further study that reported bystander-CPR rates of 38.4% in the CBD system (Dami et al., 2015). The authors argue that the different findings between the two systems could be attributed to education, experience and proficiency of the dispatchers across the two systems.

An in-house, modified dispatch tool created in Belgium by the local emergency services reported a pre-implementation rate of bystander-CPR of 9.8% and a post-implementation bystander-CPR rate of 22.5% ($p = 0.0002$) (Stipulante et al., 2014). This suggests that Emergency Call Handler guidance software does have a role to play in the rate of bystander-CPR rates of engagement.

Bystander-CPR was less likely to be initiated when the OHCA was not recognised ($p = 0.001$) and Emergency Call Handlers were less likely to recognise OHCA when the OHCA was witnessed ($p = 0.009$) (Lewis et al., 2013). This particular finding would have a profound effect on bystander-CPR rates if OHCA was not recognised. Five studies identified explicitly that agonal breathing was directly responsible and the most common reported presentation affecting the Emergency Call Handlers ability to recognise OHCA (Dami, Fuchs, et al., 2010; Hardeland et al., 2014; Lewis et al., 2013; Stipulante et al., 2014; C. Vaillancourt et al., 2015). This will ultimately have a direct impact on bystander-CPR rates.

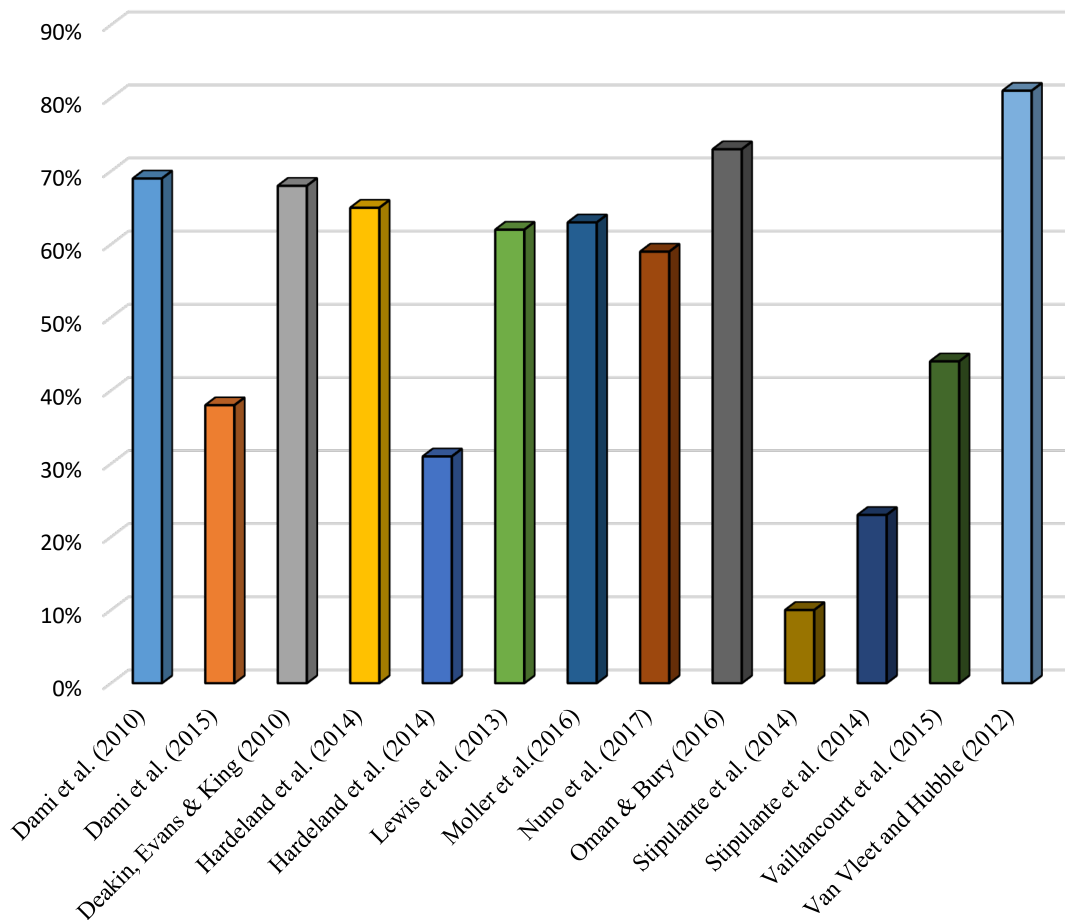

Figure 4 Summary of bystander-CPR rates

It is prudent to understand that Emergency Call Handler training and experience will have a direct influence on bystander-CPR rates. Improved bystander-CPR rates are directly related to the early recognition of OHCA, initiation of telephone-CPR and subsequently, bystander-CPR engagement.

Of the studies reviewed, Emergency Call Handler training was discussed consistently across the design of these studies. Some of the studies only described some facets of Emergency Call Handlers' background and training, while the remainder of the studies were more comprehensive in their descriptions. Five studies did not incorporate a thorough training design description into their studies (Deakin et al., 2010; Hardeland et al., 2014; Nuno et al., 2017; Stipulante et al., 2014; Van Vleet & Hubble, 2012), whereas the remaining six studies did (Dami, Fuchs, et al., 2010; F. Dami et al., 2015; Lewis et al., 2013; Moller et al., 2016; Stipulante et al., 2014; C. Vaillancourt et al., 2015). There were inconsistent lengths of training regimes across all of the studies

ranging from one day to 20 weeks in length. Four studies identified that the Emergency Call Handlers all had a clinical background in either nursing or paramedicine (Dami, Fuchs, et al., 2010; F. Dami et al., 2015; Moller et al., 2016; Stipulante et al., 2014).

Training of nurses and paramedics as Emergency Call Handlers in one study were required to complete up to 20 weeks of formal training and to then be annually reviewed to retain currency (Moller et al., 2016). The authors report a bystander-CPR rate of 62.7%. Another study conducted in the United States of America found that Emergency Call Handlers using the ProQA™ MPDS were required to complete 32 hours of medical training, six hours of which is dedicated solely to the recognition of OHCA and agonal breathing (Lewis et al., 2013). The authors report a bystander-CPR rate of 62%. By contrast, another study found that when a new dispatch tool was introduced into their service, Emergency Call Handlers only had to complete one day of formal training (Stipulante et al., 2014). This study reported a low bystander-CPR rate of 9.8% pre-introduction of their dispatch tool (“ALERT”), which subsequently increased bystander-CPR rates to 22.5% after training and introduction to the dispatch tool. This low rate of improved bystander-CPR could be attributed to the insufficient amount of training provided in the use of the new dispatch tool.

A further study describing training regimes found that while using the ProQA™ MPDS, five days of training was provided to Emergency Call Handlers of whom had both clinical and non-clinical backgrounds (Oman & Bury, 2016). This study reported a bystander-CPR rate of 73% . Two studies conducted in Denmark and Sweden note that all the Emergency Call Handlers were trained as either nurses or paramedics whom of which did not receive any formal dispatch training. The Emergency Call Handlers were allowed the freedom to ask a question and make a diagnosis as they deemed appropriate without the use of a formal dispatch tool, a bystander-CPR rate of 69% was achieved (Dami, Fuchs, et al., 2010; Dami et al., 2015). By contrast, another study found that the implementation of a CBD system tool along with nurse and paramedic Emergency Call Handlers receiving 40 hours of annual continuing education, this study only achieved a bystander-CPR rate of 38.4% (Dami et al., 2015). It was noted that Emergency Call Handlers were allowed to deviate from the dispatch tool when they deemed appropriate. The authors further suggest that the reduced rate of bystander-CPR could be attributed to the Emergency Call Handler not proposing CPR, bystander declining telephone-CPR advice or declining to perform CPR.

A further study identified a dispatch training tool developed by the Ontario Ministry of Health. This study only achieved a bystander-CPR engagement rate of 44% even though their Emergency Call Handlers all received a formal six-week training program (Vaillancourt et al., 2015). These low bystander-CPR rates may be attributed to the design and implementation of their dispatch protocol. Similarly, another study not using the ProQA ™ MPDS/CBD system also demonstrated a low bystander-CPR rate of only 59%. The authors did not mention any formal training regimes in relation to Emergency Call Handler training (Nuno et al., 2017).

The reviewed literature could not identify any correlation between training and bystander-CPR rates. The review, however, did identify that the use of the ProQA™ MPDS or CBD system did present higher rates of bystander-CPR engagement compared to when the ProQA™ MPDS or CBD system was not used.

2.4 Limitations of the published literature and review

Overall there was a varying range of sensitivity to recognition of OHCA and the time taken to commence the telephone-CPR instructions and the first chest compression by Emergency Call Handlers. Primarily, this variability may be due to differing training regimes, education and experience rather than software utilisation. The use of the ProQA™ MPDS/CBD system software did, however, increase the time taken to commence the first chest compression as opposed to the non-ProQA™ MPDS/CBD system. Additional factors which may influence the variation in times may be attributed to rescuer and Emergency Call Handlers' stress, language and communication issues and bystander refusal to assist.

The current review is subject to the limitations associated with the methods of 'semi-systematic' literature reviews. This includes the potential to miss studies due to a stringent date range and to introduce publication bias as only one reviewer was able to be resourced due to funding restrictions.

2.5 Summary

This semi-systematic review of the literature identified 11 studies which reported sensitivity of recognition of OHCA by Emergency Call Handlers along with key timeframes to the commencement of CPR and bystander-CPR rates. The PRISMA

protocol was used to ensure that the literature review met all the criteria for a semi-systematic literature review.

- The sensitivity of OHCA reviewed across the literature ranged from 66% to 90% (MPDS 80% to 86%) and specificity ranged from 32.2% to 99.7%.
- The time taken to recognise OHCA from call pick-up ranged from 60 seconds to 240 seconds (MPDS 60 seconds to 240 seconds).
- The time taken from call pick-up to commencement of the first chest compression ranged from 168 seconds to 328 seconds (MPDS 176 seconds to 328 seconds).
- Bystander-CPR rates ranged from 9.8% to 81% (MPDS 31% to 81%)

There was substantial variability in both measures of recognition and the time taken to recognise OHCA. To minimise delay, Emergency Call Handler must be able to recognise OHCA and provide telephone-CPR instructions in the shortest timeframe possible. This review does not support any particular dispatch system to help Emergency Call Handlers recognise and act on OHCA over the phone. While this review discussed findings based on whether or not a ProQA™ MPDS/CBD system was used, other factors may contribute to heterogeneity and variation between the study results. These factors include the inconsistent use of a formal dispatch tool such as the ProQA™ MPDS or CBD system, Emergency Call Handler training and experience and the year in which the study was conducted. A number of factors were identified which affected the varied timeframes identified in this review around recognition and time taken to commence the first chest compression. These factors include the presence of agonal breathing, Emergency Call Handler stress, language and communication issues and a bystanders' inability to follow instructions or refusal to assist in the first instance.

It is apparent through this review that ProQA™ MPDS/CBD systems are not utilised across the world. A number of CCS centres have either designed a dispatch tool of their own in collaboration with significant stakeholders or alternatively do not utilise a dispatch tool at all. The benefits of using a ProQA™ MPDS/CBD system are the provision of a structured algorithm for Emergency Call Handlers to follow, and a measurable compliance tools for auditing purposes. There has to date been no studies conducted in New Zealand which explore the performance of Emergency Call Handlers in the context of OHCA. There is a potential to increase recognition of OHCA and

improve the time taken to commence the first chest compression through modification of the predetermined question algorithm within the ProQA™ MPDS/CBD system.

Chapter 3 Research methods

3.1 Introduction

This chapter provides a detailed description of the methods used to investigate Emergency Call Handler accuracy. The study design, setting, population, variables, and data sources are explained, followed by a discussion of the handling of the quantitative variables and presentation of the statistical methods. This chapter will follow the Strengthening the Reporting of Observational Studies in Epidemiology structure (STROBE) guidelines (Vandenbroucke et al., 2014). These guidelines were constructed specially to improve the clarity and consistency of reporting in studies and supports a format of standardisation of measures (Carter & Lubinsky, 2015).

3.2 Aim and objective

The primary aim of this study is to establish the accuracy of Emergency Call Handler recognition of cardiac arrest. The secondary aims of this study are to measure:

(i) the time taken from emergency call pick-up to:

- the recognition of Out of-Hospital-Cardiac-Arrest (OHCA);
- the commencement of telephone-CPR instructions;
- the commencement of the first chest compression by a bystander;

(ii) bystander-CPR rates.

3.3 Study design

This study used a retrospective observational design methodology to investigate Emergency Call Handlers' recognition of OHCA. The study data were extracted from records of audio files following emergency telephone calls made to St John ambulance for OHCA. The audio files were analysed retrospectively to examine the Emergency Call Handlers' ability to recognise OHCA and to establish the timeframes associated with the recognition of OHCA, the provision of telephone-CPR instructions and to commencement of the first chest compression.

The ePRF database was accessed to extract the working diagnosis of the paramedic who attended the callout; this confirmed that an OHCA event had occurred. This

information was compared to the Emergency Call Handlers' MPDS data and the reviewed audio files from the original emergency phone call. The principal investigator was responsible for analysing the audio files and comparing them to the ePRF. The timeframes associated with the Emergency Call Handlers' ability to recognise OHCA and commencement of telephone-CPR instructions were retrieved during the analysis. This thesis aims to establish the accuracy of Emergency Call Handler recognition of OHCA. The primary outcome variable was the Emergency Call Handler's ability to accurately recognise OHCA to facilitate the early provision of telephone-CPR instructions via the MPDS. The secondary aim was to measure the time taken from emergency call pick-up to recognition of OHCA, the commencement of telephone-CPR instructions, and commencement of the first chest compression by a bystander. Finally, bystander-CPR rates were measured.

An alternative approach using a prospective cohort study design was considered. This would measure the association between the Emergency Call Handler recognition of OHCA and the patient's 30-day survival after the cardiac arrest event. However, this was not possible as the ambulance service did not have mortality data available at the time of data collection for this study. Moreover, a requirement for large case numbers and a possible lengthy timeframe to reach statistical significance was not feasible with the available resources. Therefore, the retrospective observational design was an appropriate choice with effective use of the existing data.

3.4 Setting

St John Ambulance Service provides prehospital emergency cover across most of New Zealand. St John Ambulance Service has more than 1,600 professional paid staff and over 3,000 volunteer officers which make up the workforce of the ambulance service nationally which attends to more than 1,300 calls per day (Dicker, Oliver, et al., 2018).The study was set in New Zealand at close to a national level and conducted in collaboration with the St John Ambulance Service. Audio files for all OHCA cases between 1 April and 30 April 2016 were accessed from the CCS centre. Data from the St John ePRF database for the same period was provided to the principal researcher . The data was gathered and analysed by the principal researcher between 7 May 2016 to 30 June 2016. All areas covered by St John Ambulance were included in this study. The

Wellington area, serviced exclusively by the Wellington Free Ambulance (WFA) Service was not included in this study due to the inability to access WFA data.

3.5 Study participants

The study identified participants from the St John OHCA registry. Patients of all ages, genders and both trauma and medical causes of OHCA were included in the study. A large cohort of study participants was achieved during the study period as we were able to gather OHCA data at a national level.

St John Ambulance maintains a database of confirmed cardiac arrest events for which an ambulance crew attended and completed an ePRF. All patients in the ePRF cardiac arrest database were considered for inclusion in the current study. An OHCA audit form designed by the principal researcher (Appendix 4) was used to record observations from the Emergency Call Handler audio files. The audit form design is based on a structure set out by Dameff et al. (2014). All Emergency Call Handlers utilise ProQA™ MPDS v12.0® TriTech Inform Computer-Aided Dispatch® software to triage 111 calls, provide pre-arrival and post-dispatch CPR instructions to the caller (Dicker, Davey, et al., 2018). A recording system called Redbox® within the CCS centre records the audio conversation between the caller and the Emergency Call Handler. These recordings are available for review when required.

The ProQA™ MPDS aims to safely prioritise ambulance dispatch, based on the patients' need for emergency medical care. This process is necessary to ensure that limited resources are optimised to operational demands. The ProQA™ MPDS protocol utilises a form of questioning and symptom recognition that may eliminate any Emergency Call Handler bias. It potentially nullifies any errors through the use of a scripted set of pre-arrival questions and relevant life-saving instructions (Cady, 2014). The ProQA™ MPDS protocol facilitates an initial assessment which is conducted by the Emergency Call Handler through a "Case Entry" questionnaire (Appendix 7). Case Entry questions help determine within the first 30 seconds of the Emergency Call Handler's questioning, whether a life-threatening condition exists or not. The importance of establishing whether or not the patient is alert and breathing adequately provides the first opportunity to begin telephone-CPR instructions early (Cady, 2014).

Due to the nature of the research question, the following four exclusion criteria were applied to cases; i) the Emergency Call Handler determined that the patient was clearly deceased, or ii) had an advance directive not to resuscitate, or iii) the OHCA event occurred after the Emergency Call Handler had completed a triage enquiry or iv) if the caller was not with the patient. These criteria help to identify cases where it would have been inappropriate or impossible to initiate telephone-CPR instructions.

3.6 Variables

The variables described in our study covered three areas which included patient demographics, initial clinical findings and OHCA telephone-CPR outcome variables. Patient demographic characteristics were gender, age in years, ethnicity and the location of the incident as recorded on the ePRF by the attending paramedic at the OHCA event (Table 3). The patient gender was treated as a dichotomous variable. Gender was established and recorded by the principal researcher while listening to the OHCA audio files; this was cross-checked with the ePRF data when a gender could not be established. Both age and date of birth are recorded on the ePRF. In some instances, the patient's age was also recorded by the principal researcher while listening to the OHCA recordings. In instances where ages were recorded on both the audio recordings and the ePRF, ages were cross-checked for accuracy. In cases where the two age values did not match, the final patient age was that retrieved from the St John OHCA ePRF database. Ethnicity was taken from the ePRF data; this data is, however, limited by the ethnic option fields available within the ePRF system. These option fields are consistent with New Zealand census categories which include European, Maori, Pacific Islander, Asian, Middle-Eastern and other. The patient location was retrieved from the ePRF as recorded by the attending paramedic. The location of the incident did not identify a physical address but instead described the type of area where the OHCA occurred such as private residence, public place or health care facility.

The initial clinical findings variables included the electrocardiograph (ECG) rhythm reported on arrival at the OHCA event and if bystander-CPR was in progress when the paramedic first arrived at the scene (Table 3). This data was retrieved from the ePRF. The attending paramedic reported the initial electrocardiograph (ECG) rhythm using five categories. These categories included ventricular fibrillation (VF), pulseless ventricular tachycardia (VT), asystole, pulseless electrical activity (PEA) and other.

Paramedics also recorded if bystander-CPR was in progress when they arrived. This variable was included in the data and also recorded as a dichotomous variable of yes or no. Data describing whether or not bystander-CPR was effective was not recorded. Witnessed and un-witnessed bystander-CPR was also captured on the ePRF. This data was reported as a dichotomous variable with a yes or no answer. The principal researcher recorded the presence of agonal breathing being heard or suspected during the call. The presence of agonal breathing was also reported as a dichotomous variable with a yes or no answer.

Outcome variables associated with the provision of telephone-CPR instructions included (Table 3):

i) the accuracy of OHCA recognition,

ii) the time taken from call pick-up to the recognition of OHCA

iii) the time taken for call pick-up to the commencement of telephone-CPR instructions

iv) time take from recognition of OHCA to the commencement of telephone-CPR instructions

v) the time taken from call pick-up to the to the commencement of the first chest compression

vi) the time taken from recognition of OHCA to the commencement of the first chest compression by a bystander

The accuracy of the Emergency Call Handlers' ability to correctly recognise OHCA was compared to the attending paramedics' findings upon arrival on the scene as recorded on the ePRF. The Emergency Call Handlers' crucial action times were recorded using the software within the CCS centre, which allowed playback of all the OHCA recordings across the study timeline using the Redbox® audio software system. As the Emergency Call Handler completed each action, these actions were measured and recorded by the principal researcher on a timeline. For example, a time stamp was allocated when measuring the time taken to commence the first chest compression. This occurred when the first chest compression was counted out loud by the Emergency Call Handler to assist the caller with an initial compression rate.

Table 3 *Data field description*

Data fields recorded from both audio files and ePRF
• **Demographic**
Gender, age, ethnicity, location
• **Initial clinical findings**
Bystander-CPR
Initial ECG rhythm
Agonal breathing heard or suspected
• **Outcome data of OHCA recognition and key time intervals**
Accuracy of OHCA recognition
Time taken from call pick-up to recognition of OHCA
Time taken from call pick-up to telephone-CPR instructions
Time taken from recognition to the telephone-CPR instructions
The time taken from call pick-up to the to the commencement of the first chest compression
Time taken from recognition to commencement of the first chest compression by a bystander

Notes: ePRF = electronic patient report form; OHCA = out-of-hospital cardiac arrest; ECG = Electro-cardiogram; VF = Ventricular fibrillation; PEA = Pulseless electrical activity; CPR = Cardio-pulmonary resuscitation.

3.7 Data sources and measurement

The principal researcher collected all observational data. Data sources (Table 4) included recordings of the audio calls answered by St John emergency call handlers were retrieved from the St John national database which was accessible within the CCS centre in Auckland. Time intervals were established from computer-aided dispatch (CAD) software audio recordings within the CCS centre and by using the Redbox® audio software. Further on-scene data was retrieved from the St John ePRF to examine variables that could not be identified via the audio recordings. All the data retrieved from the audio recordings and ePRF were handwritten onto the Emergency Call Handlers' CPR Instructions Audit form (Appendix 4 Audit Form) and retrospectively entered into a Microsoft Excel Spread sheet™.

Table 4 *Description of variables and data sources*

Variable name	Definition	Souce of variable	Value / Format of variable
Gender	The patients gender	ePRF and telephone	Male/ Female
Age	The patients age in years	ePRF and telephone	yyyy
Ethnicity	Patient ethnicity	ePRF	European, Maori, Pacific Islander, Asian, Middle-Eastern, other
OHCA location	Locations included were non-specific to addresses but more to areas	ePRF	Residence, public or health care facilities
ECG Rythm	Initial ECG rhythm identified upon arrival at the scene	ePRF	VF/VT, asystole, PEA or other
Bystander-CPR	The commencement of bystnder-CPR after instructions	ePRF	Yes/No
Agonal breathing heard or suspected	The researcher able to hear agonal breathing	telephone	Yes/No
OHCA recognised	Emergency Call Handler able to recognise OHCA	Redbox® and EPRF	Yes/ No
Time taken to recognition	Time taken from call pick-up to recognition of OHCA	Redbox®	mm:ss
Time taken from pick-up to commencement of CPR.	Time taken from call pick-up to the commencement of telephone-CPR instructions	Redbox®	mm:ss
Time taken from pick-up to first chest compression	Time taken from call pick-up to commencement of the first chest compression by a bystander	Redbox®	mm:ss
Time from recognition to first chest compression	Time taken from recognition to the first chest compression	Redbox®	mm:ss

Notes: ePRF = electronic patient report form; OHCA = out-of-hospital cardiac arrest; ECG = Electro-cardiogram; VF = Ventricular fibrillation; PEA = Pulseless electrical activity; CPR = Cardio-pulmonary resuscitation; ivy = year

3.8 Potential bias

Bias is defined as 'any systematic error in the design, conduct, or analysis of a study,' with information bias being recognised as one of the most common sources of bias affecting the legitimacy of some health research (Althubaiti, 2016). This study has the potential for information bias as all the data was obtained by observation by listening to telephone encounters of OHCA. A single researcher undertook data collection, and this may have introduced bias. While the use of two independent researchers would have increased the rigor of the study, it was beyond the resources available at the time.

Measurements of the delay to the recognition of OHCA, the commencement of telephone-CPR instructions and first chest compression may not always be reliable. Environmental conditions, such as noise both on the phone and in the CCS centre, made it difficult to hear at times. There is the potential that some of these observed measurements may differ if re-examined by another researcher due to systematic measurement bias. Confirmation bias may also occur as only one researcher gathered and interpreted the data. Due to the researcher's underlying thinking or perception, there is the potential for human error, including inaccuracy and misunderstanding (Althubaiti, 2016). Selection bias could be ruled out as only OHCA cases identified by St John Ambulance and local cardiac arrest registries were included during the aforementioned period.

3.9 Study size

The sample size was not predetermined. A pragmatic study period of one month was chosen, which would provide a snapshot of all OHCA cases identified in NZ. All OHCA events reported during this one-month period were included. This timeframe also determined the number of identified OHCA cases recorded nationally. Resuscitation efforts provided by both the Emergency Call Handlers and the attending paramedics were recorded.

3.10 Statistical methods

All statistical data analyses were performed using the Statistical Package for Social Sciences (SPSS) version 23 software (IBM SPSS Statistics for Windows, Version 23.0.

Armonk, NY: IBM Corp). All quantitative categorical variables were recorded and reported as frequencies and percentages.

Patient information in relation to OHCA was collected and recorded by the principal researcher. This data was recorded on an audit form (Appendix 4) while listening to OHCA audio files.

Quantitative data, both categorical and continuous variables were used in the analysis of our research. Categorical variables such as gender, ethnicity and location were described in percentages. Further categorical variables included the initial presenting ECG rhythm, the presence of bystander-CPR and agonal breathing. Continuous variables included the patients' age and times-frames associated with the provision of telephone-CPR advice. These continuous variables were described by mean and standard deviation, which were assessed for normality. Continuous variables were inspected to determine whether the distribution was normal or skewed using histograms and by obtaining skewness and kurtosis values (Pallant, 2013).

A screening test is validated by the two measures, namely sensitivity, and specificity. Sensitivity is the probability of disease being genuinely present; as sensitivity increases, the number of false negatives is suggested to decrease (Hennekens & Buring, 1987). This is described in Figure 5 below.

The sensitivity of the Emergency Call Handlers' ability to recognise OHCA was established. In this case, sensitivity was defined as the probability of the Emergency Call Handler recognising OHCA when the event was determined by the paramedic to be cardiac arrest. The sensitivity was calculated as the proportion of patients identified by the Emergency Call Handler as OHCA among all those cases where the paramedic established that the patient was in cardiac arrest. The attending paramedic's clinical impression that an OHCA had occurred was collected from the ePRF. False positives and true negatives were not obtained within the dataset provided by St John ambulance. As a result, specificity, positive predictive values, and negative predictive values were not able to be calculated. The frequency of CPR instructions associated with the provision of chest compressions was also reported in confirmed OHCA patients by the attending paramedic at the scene.

		Paramedic
Emergency Call Handlers		**OHCA Confirmed**
Recognised OHCA	**Yes**	True Positive (TP)
	No	False Negative (FN)
		Sensitivity = TP/(TP+FN)

Figure 5 Sensitivity model for Emergency Call Handler recognition of OHCA

Confirmed OHCA calls were identified from respective closing codes in the CCS centre and compared with the on-scene paramedic's findings according to the ePRF. Data that was missing in the first instance and not obtained during the initial analysis of the call was followed up and cross-checked with the ePRF. Where there were inconsistencies, the St John Cardiac Arrest-Database was accessed to ensure completeness and accuracy.

3.11 Ethical approval

The study was approved by the Auckland University of Technology Ethics Committee, #16/111 (Appendices

Appendix 1 AUT Ethics Committee Approval AUTEC 111/16). Locality approval was provided by St John, New Zealand (Appendix 2 St John Locality Agreement).

Chapter 4 Results

4.1 Inclusion/exclusion criteria

Between 1 April 2016 and 30 April 2016, 344 OHCA cases were identified and attended by St John Ambulance. One hundred and eighty (180) patients were excluded from the study due to the predefined exclusion criteria. The exclusion criteria were: where the caller was not with the victim (n=84), instances where the patient was not in cardiac arrest at the time of the call and arrested during ambulance response (n=48), obvious death (n=40) and an advance directive such as a do-not-resuscitate order (n=8). This is exhibited in Figure 6 below.

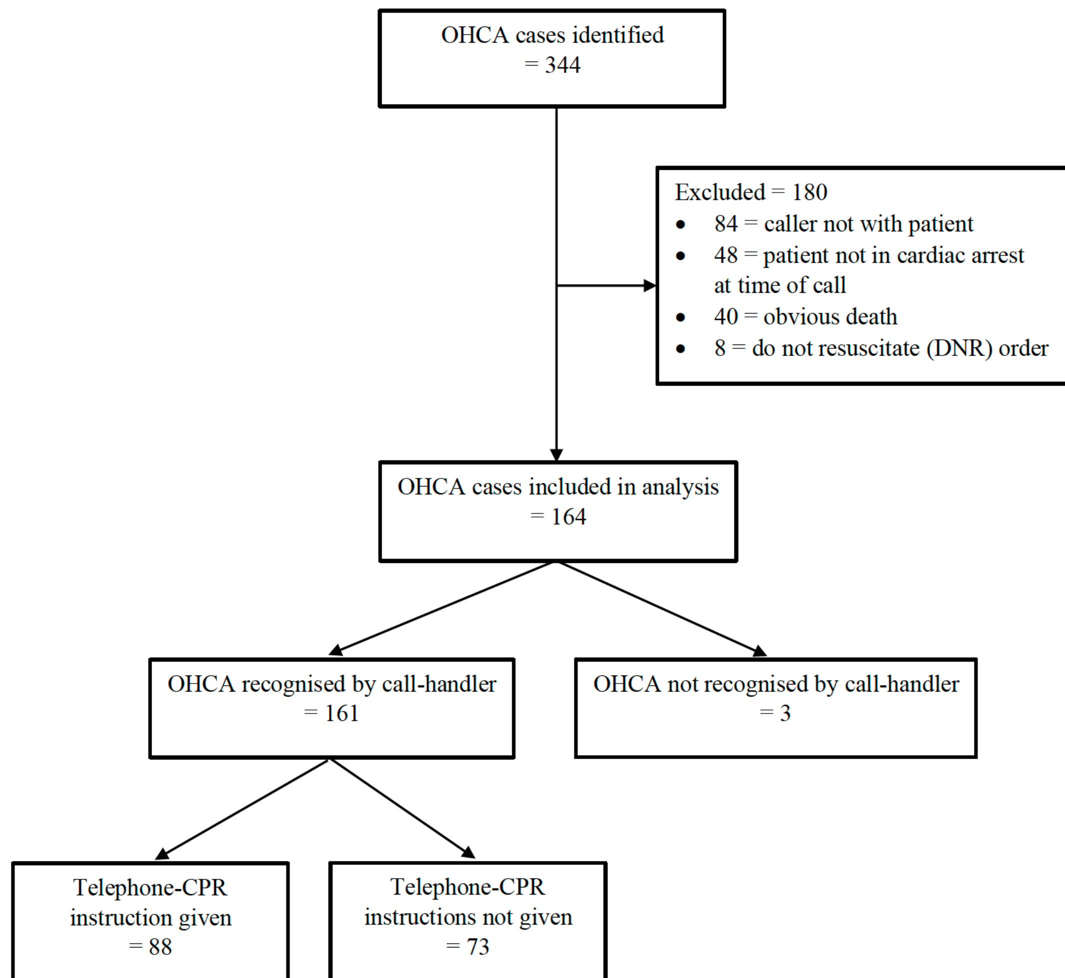

Figure 6 Inclusion / exclusion criteria
Notes: OHCA = out-of-hospital cardiac arrest; CPR = Cardio-pulmonary resuscitation.

Among the 164 cases included in the analysis, telephone-CPR instructions were provided to 88 (53.7%) callers. The remaining 76 (46.3%) did not receive CPR

instructions for various reasons (Table 5). These were grouped into five categories: 1) someone at the scene already knew CPR (23 cases), 2) communication was lost (6 cases), 3) a bystander refused to assist (8 cases), 4) a bystander had physical or emotional limitations (36 cases), 5) the Emergency Call Handler did not recognise OHCA (3 cases).

Table 5 *Reason CPR instructions were not provided*

Reason	**n**	**%**
Someone at the scene already knew CPR	23	30
Communication lost	6	8
Bystander refused to assist	8	10
Bystander physical /emotional limitations	36	47
Call handler did not recognise OHCA	3	4
Total	76	99[a]

Notes: CPR = cardio-pulmonary resuscitation; OHCA = out-of-hospital cardiac arrest.
[a] Total may not sum to 100% due to rounding.

4.2 Participants

The demographic characteristics explored in this study were the patients' gender, age, ethnicity and the type of location where the OHCA event took place (Table 6). The proportion of male patients in this study was more than twice that of their female counterparts making up 70.1% of the total cohort. The median age of all included patients was 63 (IQR 55-75) years. Children under the age of 16 years accounted for only 1.8 % of the included cases. The majority of the patients identified were of European ethnicity at 52.4%, making up more than half of the total number of included patients. Maori patients were less prevalent, making up 23.8% of the population; the remaining ethnicities included Pacific Islanders (1.2%), Asians (4.3%) and Middle-Easterners (0.6%). Patients with undetermined ethnicities made up the remaining 17.7%. Out-of-hospital cardiac arrest occurred most commonly at a private residence, making up 79.3% of the included cases. The remaining OHCA events occurred in a public place in 14.6% of the cases, and 6.1% occurred at a healthcare facility.

Table 6 *Demographic characteristics of 164 included OHCA patients*

Demographic	n	%[a]
Total population	164	-
Gender		
Male	115	70.1%
Female	49	29.9%
Age		
Median age (IQR)	63 (55 – 75)	-
Ethnicity		
European	86	52.4%
Maori	39	23.9%
Pacific Islander	2	1.2%
Asian	7	4.3%
Middle-Eastern	1	0.6%
Other	29	17.7%
OHCA Location		
Residence	130	79.2%
Public	24	14.6%
Healthcare facility	10	6.1%

Notes: IQR = Interquartile Range
[a] Total may not sum to 100% due to rounding.

The clinical characteristics of the OHCA cases in this study were examined. The characteristics included the initial presenting electrocardiogram (ECG) upon paramedic arrival at the scene (Table 7); whether the OHCA was witnessed or not and if agonal breathing was heard or suspected during the initial telephone call (Table 8). The ePRF data provided information regarding the most prevalent ECG rhythms reported upon paramedic arrival for all included cases. Of the 164 cases included in the study where OHCA was recognised, asystole was the most frequently reported presenting ECG rhythm at 53%, followed by ventricular fibrillation (VF) or ventricular tachycardia (VT) accounting for 23% of the reported rhythms. Pulseless electrical activity (PEA) was reported in 8% of the included cases followed by unknown and bradycardic rhythms making up 15% and 1% respectively. Among cases where telephone-CPR instructions were provided, the cardiac arrest was witnessed by bystanders in 51% of the events. Data were obtained from the original audio files regarding the presence of agonal

breathing. Agonal breathing was heard or suspected in 24% of these cases, no agonal breathing was heard or suspected in 73% of the cases, and agonal breathing was unknown in 3% of the cases (Table 8).

Table 7 *OHCA specific ECG statistics of all included patients*

OHCA variable	n = 164	%
Initial Rhythm		
VF/VT	38	23%
Asystole	87	53%
PEA	13	8%
Brady-Cardia	2	1%
Unknown rhythm	24	15%

Notes: OHCA = Out-of-hospital cardia arrest; VF = Ventricular fibrillation;
VT = Ventricular tachycardia; PEA = Pulseless electrical activity

Table 8 *OHCA statistics of witnessed cardiac arrest and the presence of agonal breathing only where telephone-CPR instructions were provided*

OHCA variable	n = 88	%
Cardiac Arrest Witnessed n (%)		
Yes	43	51%
No	45	49%
Agonal breathing heard or suspected n (%)		
Yes	21	24%
No	64	73%
Unknown	3	3%

4.3 Accuracy of Emergency Call Handler recognition of OHCA

Emergency Call Handlers' recognised OHCA during the emergency call was achieved in 161 of the 164 included cases. This produced a diagnostic sensitivity measure of 98.2% (Figure 7).

		Paramedic
Emergency Call Handlers		**OHCA Confirmed**
Recognised OHCA	**Yes**	True Positive (n=161)
	No	False Negative (n=3)
		Sensitivity = 161/(161+3) =98.2%

Figure 7 Sensitivity statistics for Emergency Call Handler recognition of OHCA

4.4 Time from call pick-up to recognition of OHCA

The median time taken from call pick-up to the recognition of OHCA among the 161 instances where cardiac arrest was identified was 105 seconds (IQR; 80-148) and a mean of 119 seconds (SD = 61). The minimum time recorded to recognise OHCA was 3 seconds and the maximum time was 412 seconds. The histogram in Figure 8 below reveals a right skewed distribution with two outliers noted, one at 332 seconds and the other at 412 seconds. This skewness explains the difference between the median and mean values.

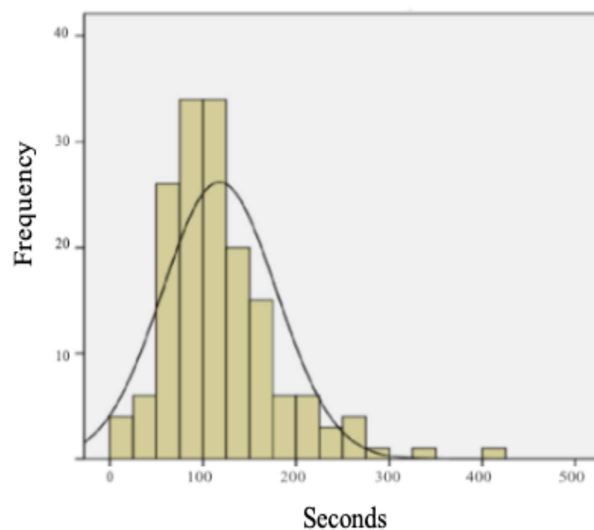

Figure 8 Histogram showing elapsed time from call pick-up to recognition of OHCA

4.5 Time from call pick-up to commence telephone-CPR instructions

The median time from call pick-up to the commencement of CPR instructions was 146 seconds (IQR; 109-212) and a of mean of 165 seconds (± SD 86). The minimum time recorded to commence telephone-CPR instructions was 20 seconds and the maximum time was 463 seconds. The histogram in Figure 9 below shows a skewness of this distribution at 1.30 with a couple of outliers noted at 435 seconds and 463 seconds. This skewness explains the difference between the median and mean values.

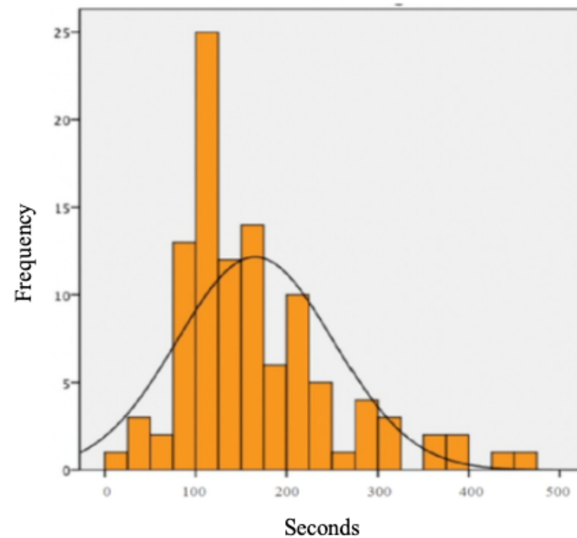

Figure 9 Histogram showing elapsed time from call pick-up to commencement of telephone-CPR instructions

In a further analysis, the time interval from recognition of OHCA and the commencement of telephone-CPR instructions was calculated. The median time from recognition of OHCA to the provision of telephone-CPR instructions was 36 seconds (IQR; 17-69) and a mean of 53 seconds (± SD 53). The minimum time recorded to commence telephone-CPR instructions was 3 seconds and the maximum time was 282 seconds. The histogram in Figure 10 below shows a skewness of this distribution is at 2.30 with a couple of outliers noted at 235 seconds and 282 seconds.

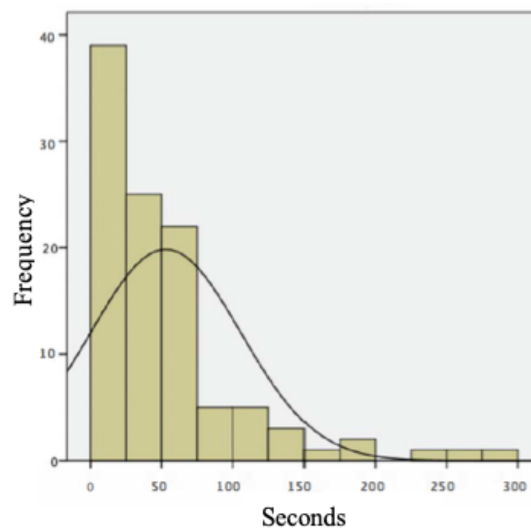

Figure 10 Histogram showing elapsed time from recognition of OHCA to provision of telephone-CPR instructions

4.6 Time from call pick-up to commence the first chest compression

The median time taken from call pick-up to the commencement of the first chest compression was 255 seconds (IQR 201-342) with a mean value of 285 seconds (± SD 128). The minimum time recorded to commence the first chest compression was 77 seconds and the maximum time was 705 seconds. The histogram in Figure 11 below shows a skewness of this distribution at 1.10 with one outlier noted at 705 seconds. Again, this skewness explains the difference between the median and mean values.

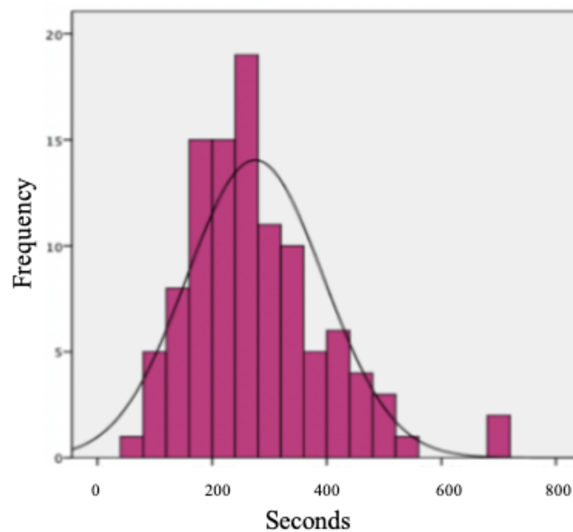

Figure 11 Histogram showing elapsed time from call pick-up to the provision of the first chest compression

The median time from recognition of OHCA to the provision of the first chest compression was 161 seconds (IQR 99-207). A mean of 165 seconds (± SD 90) was calculated for the same interval. The minimum time recorded to commence the first chest compression was 30 seconds and the maximum time was 537 seconds. The histogram in Figure 12 below shows a skewness of this distribution at 1.30 with one outlier noted at 537 seconds. This skewness explains the difference between the median and mean values.

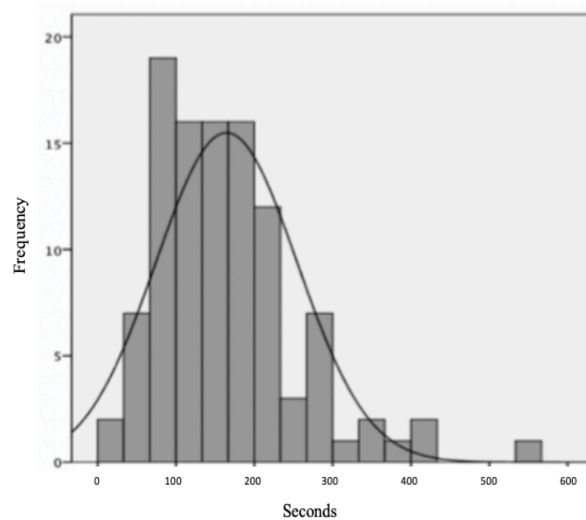

Figure 12 Histogram showing elapsed time from recognition to the provision of the first chest compression

A summary of the key time intervals is presented in *Table 9* below.

Table 9 *Summary of key time intervals in OHCA cases recognised by the Emergency Call Handler (n = 161)*

Time from	Mean (seconds)	Median (seconds)	Min and Max (seconds)
Call pick-up to OHCA recognised	119 ± SD 61	105 (IQR 80-148)	Minimum 3, max 412
Call pick-up to telephone-CPR instructions	165 ± SD 86	146 (IQR 110-212)	Minimum 20, max 463
Call pick-up to first chest compression	285 ± SD 128	255 (IQR 201-342)	Minimum 77, max 705
OHCA recognised to telephone-CPR instructions given	53 ± SD 53	36 (IQR 17-69)	Minimum 3, max 282
OHCA recognised to commencement of first chest compression	165 ± SD 90	161 (IQR 99-207)	Minimum 30, max 537

Notes: CPR= cardio-pulmonary resuscitation; OHCA = out-of-hospital cardiac arrest; SD = standard deviation; IQR = Interquartile rage; max = maximum

4.7 Bystander-CPR rates

The relationship between telephone-CPR instructions and the observation of CPR in progress on ambulance arrival was explored. Telephone CPR was provided in 88 (54%) of the 164 included cases. There were various reasons why telephone-CPR instructions were not provided in the remaining 76 cases and these were grouped into five categories.

i. The caller had a physical or emotional limitation on 36 occasions,

ii. CPR was already in progress in 23 cases,

iii. A bystander refused to assist on eight occasions,

iv. Communication was interrupted or lost in six instances,

v. The Emergency Call Handler did not recognise OHCA on three occasions.

Table 10 *Crosstabulation of telephone-CPR and bystander-CPR on Paramedic arrival*

		CPR in progress on Paramedic arrival		
		Yes	**No**	**Total**
T-CPR instructions given	**Yes**	62	26	**88**
	No	25	51	**76**
	Total	**87**	**77**	**164**

Notes: T-CPR= Telephone cardio-pulmonary resuscitation

Bystander CPR was in progress in 87 (53%) of the 164 cases when the paramedic arrived at the scene. For the 88 cases where telephone-CPR instructions were provided, bystander-CPR was in progress upon paramedic arrival in 62 (70%) (Table 10).By comparison, among the 76 OHCA cases where telephone-CPR instructions were not given, bystander-CPR was in progress when the paramedic arrived in only 25 (33%) of cases.

A Chi-square test for independence (with Yates Continuity Correction) indicated a significant association between telephone-CPR instructions and the rate of bystander-CPR engagement upon Paramedic arrival, χ^2 (1, n = 164) = 21.61, $p < 0.001$. These statistics can be viewed in Table 11 below.

Table 11 *Chi-Square: Telephone-CPR instructions in relation to bystander-CPR rates*

	Value	**df**	**Asymptotic Significance (2-sided)**	**Exact Sig. (2-sided)**	**Exact Sig. (1-sided)**
Pearson Chi-Square	23.09[a]	1	<0.001		
Continuity Correction[b]	21.61	1	<0.001		
Likelihood Ratio	23.63	1	<0.001		
Fisher's Exact Test				<0.001	<0.001
Linear-by-Linear Association	22.95	1	<0.001		
N of Valid Cases	164				

a. 0 cells (0.0%) have expected count less than 5. The minimum expected count is 35.68.
b. Computed only for a 2x2 table

The Phi coefficient above of 0.40 indicates a medium (.30) to strong (.05) effect which indicates a strong association between telephone-CPR instructions and the rate of bystander-CPR engagement upon Paramedic arrival. These statistics can be viewed in Table 12 below.

Table 12 *Correlation between telephone-CPR instructions and bystander-CPR rates*

		Value	**Approximate Significance**
Nominal by Nominal	Phi	.375	<0.001
	Cramer's V	.375	<0.001
N of Valid Cases		164	

Chapter 5 Discussion

This is the first study set in New Zealand that investigates the ability of Emergency Call Handlers to recognise OHCA over the phone, measures three critical times within the emergency call and establishes bystander-CPR rates. This chapter will summarise the key findings from the analysis in relation to the original study objectives and in the context of the literature. The limitations of this study will also be considered. Finally, the implications that this study for practice and future research opportunities are discussed.

5.1 Key results

The primary aim of this study was to establish the sensitivity of cardiac arrest recognition by the Emergency Call Handler compared to the attending paramedic. Every case included in this study had a confirmed diagnosis of OHCA. During the study period, 88 events met the inclusion criteria for patients in OHCA and who received telephone-CPR instructions. Overall, Emergency Call Handlers were able to correctly recognise OHCA with a sensitivity of 98% of all the calls analysed.

The secondary study aims of this study were to quantify three pivotal time intervals and identify the rates of bystander-CPR engagement. The first key interval was the time taken from call pick-up until recognition of OHCA. The median duration of this interval was 105 seconds (IQR 80-148). The second key interval was the time taken for call pick-up to the commencement of telephone-CPR instructions. The median duration of this interval was 146 seconds (IQR 110-212). The final key interval was the time taken from call pick-up to the commencement of the first chest compression by a bystander. This interval had a median duration of 255 seconds (IQR 201-342). Bystander-CPR was in progress in 53% of all cases when paramedics arrived at the scene of the OHCA and 70% of cases where telephone-CPR instructions were provided.

5.2 Characteristics of OHCA cases where telephone-CPR instructions were provided

Among the 164 included OHCA cases, CPR instructions were provided during 88 (54%) calls. The remaining 76 (46%) calls did not receive telephone-CPR instructions for various reasons. The two most common reasons that the Call Handler did not

provide instructions were the caller's physical or emotional limitations and that CPR was already being performed. Other less common reasons were bystander refusal to assist, interruption to communication and the Emergency Call Handler failing to recognise OHCA.

In this study, in 70% of cases where instructions were provided, the patient was male. This finding is consistent with another New Zealand study which identified that in 69% of all OHCA cases the patients were male (Dicker, Davey, et al., 2018). The median age of all 344 participants identified to have suffered an OHCA event during the aforementioned date range was 65 (IQR 54-78) years. The median age of all 164 participants included in this study was 63 (IQR 55-75) years. These findings are similar to the median age of 66 (IQR 53-77) years observed at an almost national level in the same year (Dicker, Davey, et al., 2018). The majority of OHCA events in our study occurred in the home (79%). Dicker, Davey, et al. (2018) suggest in their study that OHCA occurred in the home in 67% of the reported cases. Out of hospital cardiac arrest was witnessed by bystanders on 48.8% of occasions, similar to the findings of Dicker, Davey, et al. (2018) who observed that 53% of OHCA cases were witnessed by bystanders.

The presenting electrocardiogram (ECG) rhythm findings were not specifically explored in our study. However, in a coincidental finding among all OHCA cases the most frequent ECG rhythm identified by paramedics was asystole 53%. Paramedics reported ventricular fibrillation (VF) or ventricular tachycardia (VT) in 23% of cases, pulseless electrical activity (PEA) in 8%, brady-cardia in 1% and unknown rhythms in 15%. Possible factors contributing to the prevalence of these presenting rhythms could be the duration of the response time, a lack of bystander-CPR or the inability of the Emergency Call Handler to recognise OHCA. The frequency of the ECG rhythms mentioned above, is contrary to a study conducted by Keller and Halperin (2015). The authors reported VF 23%, PEA 32% and asystole 35 %. The authors did not report if any of the rhythms were attributed to cardiac arrest secondary to trauma, related to the provision of bystander-CPR or as a result of recognition of OHCA.

5.3 Accuracy of Emergency Call Handler recognition of OHCA

The accuracy (sensitivity) of the Emergency Call Handlers' ability to recognise OHCA was established when compared to the paramedic's diagnosis of OHCA, Emergency

Call Handlers were able to recognise 98% (161 occasions out of 164) of cases during the phone call. In comparison, the sensitivity reported in the literature ranged between 66% and 90% (Nuno et al., 2017; Vaillancourt et al., 2015). The results from our study exceed both previously published reports and the 95% recognition target recommended by the American Heart Association (American-Heart-Association, n.d).

There are several possible reasons that may account for the higher sensitivity of recognition of OHCA observed in our study. These reasons include changes over time, study design and sample, the use of the ProQA™ MPDS software tool and differences between countries. It is possible that changes to dispatch system software and improved Emergency Call Handler training and education over time may have facilitated improved recognition of OHCA. More recent studies have demonstrated higher sensitivity to recognition of OHCA due to advances in technology and a greater emphasis on quality assurance, software compliance and upgrades. This is reflected in the literature with a trend of improving sensitivity to recognition of OHCA in more recent studies. Reviewed studies conducted between 2007 and 2009 demonstrated a sensitivity to recognition ranging between 66% and 73% (Dami, Fuchs, et al., 2010). Later studies conducted between 2011 and 2013 demonstrated a higher sensitivity of 84%, 82% and 80% (Dami et al., 2015; Hardeland et al., 2014; Lewis et al., 2013). With data collection for the current study undertaken more recently in 2016, it does seem possible that improvements in performance may have contributed to the comparatively higher sensitivity of Emergency Call Handlers OHCA recognition. Other possible factors are differences in study design, sample size, the presence of agonal breathing during OHCA, use of emergency dispatch software and training.

Our study design is not substantially different to those reported in the reviewed literature. It is possible to suggest that a particular study design may contribute to differences between the sensitivity rate in our study and those observed in the literature. The studies mentioned above employed retrospective and prospective approaches. However, on inspection, these differing methods did not have an impact on sensitivity rates reported within the studies. It is feasible to argue that information bias may have had some impact on the results within the retrospective observational studies as all the data was obtained through observation by listening to telephone recordings of OHCA encounters (Althubaiti, 2016).

Similarly, study sample size did not appear to affect the sensitivity rates reported within reviewed studies. The smallest number of participants (n=42) reported a sensitivity to the recognition of OHCA of 73% (Deakin et al., 2010). Yet, a similar rate of 70% was observed in a study with over 200 participants (Oman & Bury, 2016). Our study, contrary to the research with similar sample sizes produced a sensitivity rate of 98%. This remarkable rate of sensitivity could possibly be due to a combination of using the ProQA™ MPDS software tool and adequate Emergency Call Hander training with good quality assurance and auditing processes. While larger samples more closely approximate the population within a study, studies with a smaller sample size have a higher risk of unusual, chance results.

Agonal breathing is common during and after cardiac arrest, and it is associated with increased survival to discharge (Zhao et al., 2015). Agonal breathing has been identified as the most critical reason for not recognising OHCA (Hardeland et al., 2014). Unfortunately, agonal breathing is commonly mistaken for normal breathing and is independently associated with a significant reduction in the likelihood that bystander-CPR will be commenced (Brinkrolf et al., 2018). Additional Emergency Call Handler training must be considered to help improve and distinguish agonal breathing from normal breathing. Agonal breathing was heard in 24% of the cases in our study, where telephone-CPR instructions were provided. The reason our rates of sensitivity to the recognition OHCA were not affected by the presence of agonal breathing may be attributable to the use of the ProQA™ MPDS software tool. The ProQA™ MPDS software tool has been described as an appropriate tool which helps facilitate the accurate recognition of agonal breathing (Clawson, Olola, Scott, Heward, & Patterson, 2008).

The effects of the use of emergency dispatch software and the level of Emergency Call Handler training within the literature were inconsistent. The literature suggests that the use of a formal dispatch tool such as the ProQA™ MPDS or the CBD system tool facilitates improved clinical accuracy, efficiency and professionalism along with minimisation of potential mistakes (Cady, 2014). The reviewed literature identified a rate of sensitivity to the recognition of OHCA to range between 66% to 90% in the studies which did not use a formal dispatch system tool (Dami, Fuchs, et al., 2010; Nuno et al., 2017; C. Vaillancourt et al., 2015). The lowest rate of sensitivity to the recognition of OHCA identified in the reviewed literature was 66% (95% CI, 63.5-

68.2%) (Vaillancourt et al., 2015). The authors suggest that this low sensitivity may have been attributed to not utilising a formal dispatch tool like the ProQA™ MPDS software or similar. By contrast, a study conducted in Denmark and Sweden reported on the sensitivity of recognition of OHCA in the two countries at 80.7% and 86% respectively (Moller et al., 2016). Both Scandinavian countries used the same emergency dispatch software (non-ProQA™ MPDS). The study above describing the high rate of the sensitivity of 90% did not identify which or if any software was used to help achieve this high rate of sensitivity (Nuno et al., 2017). All of the studies who used either the ProQA™ MPDS or the CBD system reported varying rates of sensitivity ranging between 70% to 86% (Moller et al., 2016; Oman & Bury, 2016).

Training of Emergency Call Handlers varied substantially across the literature, ranging from no formal training to 20 weeks in length. The Emergency Call Handlers in these studies also had varying clinical backgrounds ranging from no clinical training to being qualified nurses or paramedics (Dami, Fuchs, et al., 2010; F. Dami et al., 2015; Moller et al., 2016; Stipulante et al., 2014). The level of Emergency Call Hander training could also be a contributor to the differing observed sensitivity rates.

This study reported a comparatively high sensitivity of 98% in the recognition of OHCA. However, the reason for this cannot be identified. The level of training provided to the Emergency Call Handlers was not explored. It is possible that the amount of Emergency Call Handler training received, and the quality and auditing processes used at St John New Zealand contributed to achieving such a high sensitivity to the recognition of OHCA. When the ProQA™ MPDS is used correctly by Emergency Call Handlers for OHCA, the system has been shown to increase the sensitivity of recognition of patients in cardiac arrest by 200% (Clawson et al., 2012; Heward et al., 2004). The high sensitivity to the recognition of OHCA in this study may also be associated with the regular use of a the ProQA™ MPDS

The sensitivity to OHCA recognition must remain high. A high rate of recognition of OHCA will ensure that telephone-CPR is provided promptly to help reduce the high rates of mortality associated with OHCA. A high rate of sensitivity to the recognition of OHCA can be achieved through the ability to recognise agonal breathing as irregular or absent breathing. Frequent training, auditing and the use of a formalised dispatch tool such as the ProQA™ MPDS software tool will ensure that this integral process of recognition is achieved.

5.4 Specificity to recognition of OHCA

The specificity to recognition of OHCA was not examined with this study as the calls where patients were not in OHCA at the time of the call were excluded. These OHCA occurred either before the time of the call or before or after the arrival of the ambulance. The literature review identified that only two studies reported on specificity because not all of the participants involved in their respective studies were in OHCA at the time of the call (Deakin et al., 2010; Vaillancourt et al., 2007). In some instances, the Emergency Call Handlers may prefer to commence telephone-CPR instructions when in doubt to avoid getting it wrong. In this study, the exclusion of all patients who were not in cardiac arrest during the call meant that true negative cases identified by the call handler were not included. The reason for any false-negatives within this study were not routinely recorded. However, it is known that the presence of agonal breathing mimicking normal breathing, prolonged and unnecessary use of the breathing diagnostic tool (Appendix 6) and caller stress decrease the Emergency Call Handlers' ability to recognise OHCA (Bohm et al., 2009; Roppolo et al., 2009).

Telephone-CPR instructions should be reviewed to ensure that specificity in recognition of OHCA does not continue to remain low in some countries. There is currently too much time spent on determining the presence of normal or agonal breathing. Further research to identify specificity in OHCA is imperative.

5.5 Key time intervals

The key time intervals associated with telephone-CPR are commonly reported metrics within the Emergency Medical Services sector. These include the time taken from call pick-up to recognition of OHCA, the initiation of telephone-CPR instructions and the commencement of the first chest compression. These three-time intervals relate to crucial sequential steps in initiating bystander-CPR early. Firstly, the time taken to recognise OHCA is the timeframe measured between call pick-up and the recognition of OHCA. It is considered to be the most important timeframe as it does not only ensure that telephone-CPR instructions a promptly provided but also ensures that the presence of OHCA is recognised in the first instance. Any failure or delay in the recognition of OHCA may increase the delay to commence telephone-CPR instructions and subsequently the first chest compression. Secondly, the time taken to commence telephone-CPR instructions is described as the time taken from call pick-up to the

commencement of telephone-CPR instructions. This timeframe will be extended by any delay in the initial recognition of OHCA. Lastly, the interval associated with the commencement of the first chest compression is the time taken from call pick-up to the physical provision of the first chest compression. This stage of the telephone-CPR process is inherently linked to the two previous measures.

Several factors may influence the duration of each interval and the overall time taken to commence the first chest compression. Some of these factors include the presence of agonal breathing and the possibility of the Emergency Call Handler therefore not recognising OHCA in the first instance (Brinkrolf et al., 2018). Other factors include communication issues such as language barriers, bystanders refusing to assist with CPR and the physical and/or emotional limitations of bystanders.

5.5.1 Time from call pick-up to recognition of OHCA

The time taken from call pick-up to the recognition of OHCA during an emergency call is essential and regarded as a prerequisite for telephone-CPR (Viereck et al., 2017). Survivability is said to decreases by 3-5% for every minute of delay in the provision of CPR (Hardeland et al., 2014). In our study, the time taken from call pick-up to the recognition of OHCA had a median time of 105 seconds (IQR 80-148) and a mean time of 119 seconds (± SD61). Very short times (for example a 3-second delay to recognition) could be achieved in special circumstances, for example if a medical professional made the call and immediately identified themselves and stated that a patient was in cardiac arrest. The median time identified in our results falls short of the recommended goal time to recognise OHCA suggested by the American Heart Association of 60 seconds (American-Heart-Association, n.d). Our call pick-up to recognition interval was longer than the median time of 60 seconds to recognise OHCA in studies located in Switzerland and Ireland (Dami et al., 2015; Oman & Bury, 2016). Of interest, both of those studies, used substantially different sample sizes of 145 and 1,256 confirmed OHCA patients while reporting an identical interval. Other studies have reported longer time intervals. For example, call to recognition delays of a median time of 180 seconds in the United Kingdom (Deakin et al., 2010) and 240 seconds in the USA(Van Vleet & Hubble, 2012). As described in section 5.2 concerning the sensitivity to the recognition of OHCA, there also appears to be a temporal trend with the time taken to recognise OHCA correctly. In research conducted between 2007-2008, the authors reported a time taken to recognise OHCA of 180 seconds (Deakin et al., 2010).

In comparison, more recent studies conducted between 2010-2011 reported a shorter time taken to recognise OHCA of 75 - 87 seconds (Lewis et al., 2013; Nuno et al., 2017) and others between 2012-2013 reported 60 seconds (Dami et al., 2015; Oman & Bury, 2016). This suggests that the time taken to recognise OHCA has improved over time and may continue to do so as technology and greater emphasis is placed on reducing the time intervals associated with the provision of telephone-CPR instructions. However, our results stand outside this trend. We could not identify a specific cause for the prolonged delay in recognising OHCA. One possible explanation may be the experience and training of the Emergency Call Handlers. Unfortunately, the only study, where Emergency Call Handlers were trained nurses and paramedics did not report the time taken to recognise OHCA (Moller et al., 2016). Further possible explanations that may have contributed to the delay in the recognition of OHCA could be inappropriate additional questioning contrary to the ProQA™ MPDS guidelines and unnecessary repeated breathing checks utilising the ProQA™ MPDS Breathing Assessment Tool found in appendix 6 (Bohm et al., 2009). Other factors potentially affecting the Emergency Call Handlers' ability to recognise OHCA include language barriers, compliance with the ProQA™ MPDS and more commonly, the presence of agonal breathing.. (Dami et al., 2015; Nuno et al., 2017; C. Vaillancourt et al., 2015).

Data in relation to the Emergency Call Handlers' level of training was not collected in our study. This data would be useful information to include in future studies. Emergency Call Handler training is inconsistent across studies ranging from no formal training to 20 weeks of formal training and including clinicians giving adlib advice to callers (Dami, Fuchs, et al., 2010; Dami et al., 2015; Moller et al., 2016).

Language barriers are suggested to be an additional cause of delay and a hindrance in recognition of OHCA and subsequent delay in commencement of early CPR (Nuno et al., 2017). The American-Heart-Association (n.d) suggests that language barriers prolong recognition of OHCA drastically. A study conducted in the United States reinforces this sentiment that there is a strong relationship between a language barrier and significant delays in the Emergency Call Handlers' ability to recognise OHCA. These language barriers will subsequently result in an immense delay in the provision of telephone-CPR instructions. (Nuno et al., 2017). The study identified that telephone-CPR instructions were commenced, on average, in 144 seconds with no language barrier and in 241 seconds with a language barrier. These stark differences in time may

have an immense impact on survival. Our study identified one call that had a language difficulty. We, however, did not specifically study the impacts that English as a second language (ESL) may have had on the Emergency Call Handlers' ability to recognise OHCA promptly. Further research is needed in this setting to determine if ESL does, play a role in the delay or failure to recognise OHCA in the New Zealand context. This is important due to the increasing diversity of the New Zealand population.

Agonal breathing may at times be difficult to distinguish from normal breathing, especially for untrained individuals. Agonal breathing is a confounding factor in this study as it is known to inhibit the recognition of OHCA (New Zealand Resuscitation Council, 2016). Agonal breathing was heard in 24% of the cases in this study. The relationship between agonal breathing, delay in OHCA recognition and bystander-CPR was not measured. Agonal breathing was shown to be present in many of the studies reviewed in the literature. Several studies identified that agonal breathing was directly responsible and the most common reported presentation affecting the Emergency call Handlers' ability to recognise OHCA (Dami, Fuchs, et al., 2010; Hardeland et al., 2014; Lewis et al., 2013; Stipulante et al., 2014; C. Vaillancourt et al., 2015)
Agonal breathing cannot be shown to be directly responsible for the two per cent of cases where OHCA was not recognised in our study. A study with a larger sample size must be conducted to establish the exact effect that the presence of agonal breathing may have on the recognition of OHCA.

5.5.2 Time from call pick-up to commence telephone-CPR instructions

No studies were found that reported on the time taken from call pick-up to the commencement of telephone-CPR instructions. This study identified a median time from call pick-up to commence telephone-CPR instructions of 146 seconds (IQR 110-212). The median incremental interval from recognition of OHCA to telephone-CPR instructions was 36 seconds (IQR 17-69).

There is still a substantial time delay between telephone-CPR instructions and the physical provision of the first chest compression. In this study, telephone-CPR instructions were delayed due to the bystander being too emotional or physically unable to move the victim to the floor or a hard surface. The provision of voluntary bystander-CPR may also be directly related to the inability of the bystander to perform the act of chest compressions. Our study identified 42% of the cases where the Emergency Call Handler recognised OHCA but could not commence telephone-CPR instructions due to

callers' physical limitations. In 5% of the cases, the caller was too emotional to follow the Emergency Call Handlers' instructions; one caller had a language barrier, and one patient was actively choking. The ProQA™ MPDS OHCA protocol has been changed in recent times to accommodate for choking. This new protocol means that there will be no more attempts made to remove a foreign body from the airway. Instead, chest compressions are now commenced routinely to help clear any potential obstructions in the airways and may also provide circulation if the heart has stopped pumping.

Older bystanders are far more limited in their ability to initiate CPR when required. While our study identified that the inability to move the patient did not impede the ability of the Emergency Call Handler to recognise OHCA, it did in most cases result in a delay in the provision telephone-CPR instructions and in some instances, delivery of chest compressions did not occur at all. The proportion of events in this study where physical limitations were identified was slightly lower than those observed in Switzerland where of 101 cases where bystander-CPR was refused, 37 (36.6%) declined due to physical limitations. The Swiss research concludes that the rate of bystander-CPR may continue to decrease as the population ages and live longer and physical constraints become the norm (Dami, Carron, Praz, Fuchs, & Yersin, 2010). The inability to move the patient to a hard surface in OHCA has been identified as a common reason for the delay in commencing chest compressions (Hauff et al., 2003; Ho et al., 2016; Langlais et al., 2017). It has been established that the median age of the New Zealand population as at 2015 was 37.3 years and the median age of the population in Switzerland as at 2015 was 42.2 years (Statista, 2015). This difference in median ages, while only slightly different could explain the slightly higher rates of physical limitations within the Swiss study.

Another suggested cause of delay was the use of the ProQA™ MPDS (Oman & Bury, 2016). Repeated questioning around patient condition as guided by the ProQA™ MPDS was the most common cause of prolonged delays. Other factors that could contribute to the delay in telephone-CPR instructions were caller compliance, ambient noise, lucidity of the instructions provided and overall skill of the Emergency Call Handle (Lerner et al., 2012).

Language barriers impact on the overall process of commencement of telephone-CPR. Delays to both the commencement of telephone CPR instructions and the recognition of OHCA have been attributed to limited English proficiency (Bradley et al., 2011;

Meischke et al., 2015). Proficient English callers were able to initiate CPR instructions more quickly than non-proficient callers (163 vs. 237 seconds; $p = 0.001$). A study conducted in Perth, Australia suggests that the style of language used to instigate the commencement of CPR may also impede the commencement of bystander-CPR in some instances (Riou et al., 2018). Bystanders are more willing to perform CPR when Emergency Call Handlers are trained to initiate CPR instructions using terms of futurity and duty. The research identified that only 43% of callers were willing to perform CPR when asked "do you want to do CPR?" compared to 97% engagement when terms of duty such as "we are going to do CPR" was used. (Riou et al., 2018). This finding reinforces a potential need to review the current language used within New Zealand CCS centers and a need to propose alternative words to help improve clarity around telephone-CPR instructions and bystander-CPR engagement.

It is imperative for Emergency Call Handlers to understand the clinical relevance of the time taken to commence telephone-CPR instructions. A reduced time in the commencement of telephone-CPR instructions has the ability to provide a quick form of artificial circulation that helps oxygenated blood reach the brain, heart, vital organs and life-sustaining cells. The role of telephone-CPR is well described in a plethora of literature describing its ability to potentially help save a life.

5.5.3 Time from call pick-up to commence the first chest compression

The time taken to commence the first chest compression was measured at two different time intervals. These intervals were the time taken from call pick-up and from the recognition of OHCA to the commencement of the first chest compression. This study identified the time taken from call pick-up to commencement of the first chest compression had a median of 255 seconds (IQR 201-342) This interval falls well outside of the minimum acceptable standard of less than 180 seconds prescribed by the American Heart Association((American-Heart-Association, n.d). However, the median time taken from call pick-up to the commencement of the first chest compression was similar to studies reported in the literature. These studies reported median delays of 240 seconds and 280 seconds while utilising the ProQA™ MPDS.(Deakin et al., 2010; Van Vleet & Hubble, 2012).

In considering the delay to initiation of CPR, it was important to also measure the incremental time taken from recognition of OHCA to the commencement of the first chest compression. This study observed a median delay of 161 seconds (IQR 99-207).

This timeframe of 161 seconds also falls outside of the prescribed acceptable standard of less than 120 seconds (American-Heart-Association, n.d). Unlike the recognition of OHCA and the timeframes associated with it, our study was unable to establish a temporal trend in relation to the recency of a study and the shortest reported timeframe to commence the first chest compression. The shortest timeframes associated with the commencement of the first chest compression from call pick-up were reported to be 168 seconds, 174 seconds and 176 seconds respectively (Lewis et al., 2013; Nuno et al., 2017; Stipulante et al., 2014). Among these, the only study to use the ProQA™ MPDS was used by Lewis et al. (2013) who reported the shortest delay of 168 seconds. In contrast, the longest delay to commence the first chest compression from call pick-up while using the ProQA™ MPDS was 328 seconds reported by Oman and Bury (2016). Their study also reports one of the shortest delays in the time taken to recognise OHCA of only 60 seconds. Our results support the ideas of Oman and Bury (2016), that long delays are due to extended periods focusing on obtaining an address, repeated questioning in relation to the patient's condition and the recurrent breathing checks.

There are several reasons for the delay in the time taken to commence telephone-CPR instructions and the first chest compression. A likely explanation for these delays include the inability to move the victim to the floor or a hard surface; heightened caller stress levels; not being able to complete the steps involved in opening the patient's airway and the ProQA™ MPDS does not facilitate early recognition of OHCA and provision of telephone-CPR instructions. (Langlais et al., 2017).

The inability to move a patient to a hard or firm surface and emotional limitations are common issues described across much of literature and are associated with reduced rates of telephone-CPR instructions and delays in the provision of the first chest compression (Langlais et al., 2017). Our study identified that the inability to move a patient to a hard surface and the callers' emotional limitations were identified as notable hindrances to the commencement of telephone-CPR instructions. Of the 164 cases included in our study, 47% did not receive telephone-CPR instructions due to the inability to move the victim to hard or emotional stress resulting in failure to comply with instructions (Ho et al., 2016). As this seems to be quite an alarming statistic, it may be feasible to consider a change to the ProQA™ MPDS which will allow the Emergency Call Handler to continue to provide telephone-CPR instructions regardless of the caller being unable to move the victim to a hard surface. This small change may

have a significant impact on patient outcome as the provision of some form of chest compressions may be better than none at all.

The most likely cause for the ProQA™ MPDS to delay telephone-CPR is that it has too many questions in the lead up to telephone-CPR instructions (Oman & Bury, 2016). These suggestions are supported by the findings in our study. There were significant delays in the commencement of the first chest compression from both call pick-up and the initial recognition of OHCA.

The opening of an patent's airway has also played a significant role in the delay in time taken to commence the first chest compression (Clegg et al., 2014). Attempting to open a victim's airway and to be able to complete the steps involved can be quite challenging for the untrained bystander. Some additional off-script coaching and Emergency Call Handler training could potentially alleviate the pressure and stress involved with attempting to open an airway. The off-script coaching may facilitate a greater desire to assist in the provision of CPR but may also protract the time taken to commence the first chest compression. Recent changes to the ProQA™ MPDS have removed the need to open a patient's airway unless the cause of the OHCA is drowning or choking. If the primary cause of the OHCA is cardiac related, then compression-only-CPR is provided as soon as possible. As a result of this change, more specific telephone-CPR instructions focusing on chest compression-only-CPR as opposed to conventional CPR has been shown to have a more significant effect on improving outcomes. Conventional CPR is described to include the provision of chest compressions and MTMV. This cycle of 30 compressions to 2 ventilations (30:2) is also known as interrupted chest compressions with pauses at fixed stages to facilitate the administration of ventilations (Norris & O'Brien, 2012). The issue with the interrupted chest compressions to provide recue breaths is that it stops all circulation through the chest compressions while the ventilations are being provided. This action reduces the amount of blood circulation around the body and has the ability to reduce improved outcomes from OHCA (Svensson et al., 2010). There is some evidence suggesting that t compression-only CPR reduces the time from call pick-up to commencement of the first chest compression (Dias et al., 2007; Nishiyama et al., 2008). Emergency Call Handlers can move directly to chest compressions-only-CPR once it is determined that breathing is absent or abnormal. In attempting to provide ventilation in instances such as paediatrics, drowning and choking, chest compressions are interrupted. These pauses decrease the effectiveness of CPR (Zhan, Yang, Huang, He, & Liu, 2017).

In light of the evidence supporting the early provision of telephone-CPR, it is prudent to consider the impact of telephone-CPR instruction by Emergency Call Handlers before the arrival and intervention of paramedics. The quality of the chest compressions, in particular the rate and depth, cannot be evaluated during telephone-CPR. To date, there is no system available that could evaluate this crucial component of telephone-CPR.

In summary, a delay in the commencement of the first chest compression during telephone-CPR is attributed to several of possible causes. Frequent and ongoing Emergency Call Handler training and development and the provision of compression-only-CPR has been shown to reduce the time taken to commence the first chest compression. The causes of delay in the commencement of the first chest compression requires review, quality assurance measures and remedial training, where indicated, to ensure the effectiveness and reduce delays in the provision of this life-saving procedure (Lerner et al., 2012).

5.6 Bystander-CPR rates

Bystander-CPR is a commonly measured variable across much of the reviewed literature. Bystander-CPR rates are directly related to community training programs and Emergency Call Handler directed telephone-CPR instructions. Bystander-CPR has been demonstrated to more than double survival rates as bystander-CPR is associated with a greater likelihood of a patient being found in a shockable rhythm such as ventricular fibrillation (Iwami et al., 2009).

In this study, bystander-CPR was in progress upon paramedic arrival in 70% of the cases where OHCA was recognised and telephone-CPR instructions were provided. The results in our study indicate a significant association between recognition of OHCA, the provision of telephone-CPR instructions and the rate of bystander-CPR engagement upon paramedic arrival ($p = 0.001$).

Bystander-CPR rates varied widely across the reviewed literature ranging between 22.5% and 81%. The bystander-CPR rates achieved while using the ProQA™ MPDS ranged between 38.4% and 81% (Dami et al., 2015; Van Vleet & Hubble, 2012). The bystander-CPR rates achieved when no ProQA™ MPDS tool was used ranged between 22.5% and 69% (Dami, Fuchs, et al., 2010; Stipulante et al., 2014).

The reasons for the lack of bystander-CPR engagement were not explored. Our study did not differentiate between witnessed and unwitnessed bystander-CPR rates. Our results are comparable with local, contemporaneous bystander-CPR rates of 72% reported in 2016 and 74% in 2017 (Dicker et al., 2017; Dicker, Oliver, et al., 2018). While increased bystander-CPR rates are associated with Emergency Call Handler recognition of OHCA, it is prudent to recognise that these higher rates of bystander CPR over the two time periods could possibly be attributable to other factors, such as community education and training programs.

Both of these aforementioned bystander-CPR engagement rates fall below the recommended performance goal of 75% bystander-CPR engagement set by the American Heart Association (American-Heart-Association, n.d). The 2016 and 2017 New Zealand rates of bystander-CPR are similar to the other rates reported by Oman and Bury (2016) of 73% while using the ProQA™ MPDS tool and suggest improvement over time.

Contrary to the New Zealand bystander-CPR rates, bystander-CPR rates in Australia have been reported at only 42% despite a high identification rate of OHCA by Emergency Call Handlers of 85% (Bray et al., 2017). Our study also identified that in cases where telephone-CPR instructions were not given, bystander-CPR was only in progress in 32.9% of the cases when paramedics arrived at the scene.

There are several reasons for a low rates of bystander-CPR engagement, some of which have already been identified earlier in this thesis. These reasons include fear of infections, believing the patient is already dead, fear of hurting the patient and both physical and emotional limitations. Other reasons for not performing CPR once advice was provided include callers not understanding the instructions, language issues and the caller believing the patient is alive, possibly due to the presence of agonal breathing (Dami, Carron, et al., 2010; Langlais et al., 2017).

Bystander-CPR forms an integral part of the “chain of survival” described in Figure 1 and potentiates positive patient outcomes from OHCA (Bobrow & Panczyk, 2018). Recent studies suggest that patients who have received bystander-CPR are more than twice as likely to survive from an OHCA event than those who did not receive bystander-CPR (Beck et al., 2018). Bystander-CPR is dependent on Emergency Call Handler recognition of OHCA and the provision of telephone-CPR instructions. As per

the Global Resuscitation Alliance (GRA) recommendations, it is imperative that community CPR and AED education programs become more readily available to the public to ensure a greater rate of bystander-CPR engagement (Nadarajan et al., 2018). Telephone-CPR must continue to become standard practice during OHCA events to also ensure that high quality bystander-CPR rates are constantly achieved to help reduce mortality rates from OHCA.

5.7 Study limitations

There are several limitations to the current study and these will be discussed in this section. These limitations include the study design and methods, the absence of the Emergency Call Handler, caller and bystander demographics, unconfirmed cardiac arrest at the time of the call and psychological stress. Further limitations include lack of benchmarking of the ProQA™ MPDS, and researcher bias.

This study used a retrospective, observational study design. A complication of this study design is that data may be lost or be incorrectly interpreted (Ramirez-Santana, 2018). In this study, the reason for Emergency Call Handlers' inability to recognise OHCA was unclear on several occasions. The retrospective design of the study design did not allow for these reasons to be identified due to the passage of time. In a prospective study it may be possible to follow-up and discuss the case with the call handler in these instances. However, such a study was beyond the resources available.

The available resources also impacted on the study duration. This study reviewed a relatively small sample of cases. It is recommended that any future studies be undertaken over a longer period to increase sample sizes.

Single reviewer bias due to financial constraints only allowed for one principal investigator to capture and analyse the results; this has the potential to lead to bias as cross-checking of data could not be achieved. This lack of cross-checking opens the possibility for errors and information bias to occur due to missing data or due to variables that were not considered in the first instance (Ramirez-Santana, 2018).

The demographic information of the Emergency Call Handlers' level of training and duration of employment was not collected. Additionally, demographic information on the caller, such as age and knowledge of CPR or experience, were not explored. These factors could provide insight into the potential causes for the delay in recognition of

OHCA and the provision of adequate CPR in some OHCA patients. We recommend their inclusion in similar future studies while acknowledging they will be difficult to obtain, especially for callers.

The Emergency Call Handler may not have recognised OHCA because the patient was not in OHCA at the time of the call. The patient may have subsequently developed OHCA, either before or after the arrival of the paramedic.

An OHCA event is a stressful situation for all parties involved, including both the Emergency Call Handler and the caller. This can make the analysis of these events quite challenging. Some facets, like the ability to recognise or hear breathing due to background noise or language barriers where interpretation is immediately required, could alter personal judgement and interpretation and may have an impact on the overall results.

The data output achieved within this study was limited to the ProQA™ MPDS, which included the compression-only CPR protocol. Benchmarking prior versions of the ProQA™ AMPDS was not possible. Therefore, it was not possible to determine if the implementation of the compression-only CPR protocol reduced the time taken to commence the first chest compression. A further limitation of this study is that Emergency Call handler compliance with the MPDS protocols was not explicitly examined. This study does however reflect the overall ability of the Emergency Call handler to select the appropriate relevant MPDS script in cases of OHCA, follow the script without individual variation and the appropriateness of the MPDS OHCA script itself.

Furthermore, the effect of the CCS centre's operational activity was not considered about staffing levels and workload ramifications and how this may potentially impede or enhance OHCA recognition and time taken to recognise OHCA and commence early chest compressions.

This thesis does not serve to validate the use of the ProQA™ MPDS but serves to identify the Emergency Call Hander's ability to recognise OHCA. This thesis also serves to quantify the timeframes associated with the use of the ProQA™ MPDS in the OHCA setting and the rates of bystander-CPR engagement.

5.8 Recommendations for future research

There are still many unanswered questions about the sensitivity to recognition of OHCA and the timeframes associated with the commencement of telephone-CPR and the provision of the first chest compression. To develop a better understanding of the telephone-CPR process and the associated timeframes, future studies on the current topic are advised. We identified a number of important considerations for future research and will discuss each in this section.

A larger sample size of OHCA patients must be considered in future research initiatives. To develop a better understanding of the Emergency Call Handlers' and the caller's demographics and experience, specific characteristics will also need to be collected. Emergency Call Handler demographics could include: age, gender, length of service, experience and training. Furthermore, the demographics of callers could include age gender, physical ability, previous CPR training. There are, however, significant ethical considerations to ponder when attempting to obtain these specific demographic variables. Future studies which take these variables into account will potentially divulge the impact that Emergency Call Handlers and callers have on the outcome of a patient who has suffered an OHCA.

Language barriers have shown to be a significant hinderance to the recognition of OHCA and the telephone-CPR process. An investigation into the effect of language barriers on the provision of telephone-CPR instructions is an important issue for future research. Further research will also provide insight in the what steps could be taken to minimise these barriers. This is a necessity and warranted given the multicultural composition of the New Zealand population and the impact that language deficits have on patient outcome.

A multicentre observational cohort study is needed, which involves all the clinical communication service centres currently using either the ProQA™ MPDS with a comparable amount of training provided before the independent use of the tool. Several questions remain unanswered regarding the efficacy of the ProQA™ MPDS tool. Further research should be undertaken to investigate the sensitivity and specificity of Emergency Call Handlers using the ProQA™ MPDS tool and reasons for failing to recognise OHCA in the first instance. These findings can then be compared, and barriers to the provision of early telephone-CPR can be examined further. This study

may also reveal potential causes for the delay in the provision of telephone-CPR and provide insight into current bystander-CPR rates.

In future investigations, it may be possible to use a different approach to how we currently confirm if a patient is experiencing an OHCA event or agonal breathing by using the ProQA™ MPDS tool. Future research could validate if smartphone video technology has a role to play in assisting Emergency Call Handlers to recognise OHCA, determine agonal breathing and support the quality of the CPR delivered. Moreover, further work is required to establish the viability of the use of this technology which may also improve chest compression rates with improved hand placement during compressions (Lin et al., 2018).

The requirement to move a patient to a firm surface may impede the rapid commencement of chest compressions. While there is little evidence to support this, some studies have suggested that there is no difference in chest compression quality when performed on alternative hard surfaces such as chairs or some home mattresses (Ahn et al., 2019). Further research is required in this area as moving the patient prior to commencing bystander CPR is often difficult for the rescuer and may act as a disincentive to help.

The ProQA™ MPDS appears to be complex and difficult to navigate at times, so it may be prudent to ask a caller to commence chest compressions when a patient has been identified to be unresponsive and not breathing. This presents an opportunity for future research to investigate the parameters and prompts required to commence chest compressions.

Single researcher bias must be avoided at all cost. Future research initiatives must have sufficient funding in place to avoid single researcher bias by increasing research staff capacity. Additional researchers will ensure that cross-checking of data is achieved and may also provide a source for debriefing and emotional support after listening to such emotionally and disturbing telephone calls.

5.9 Implications for practice

The findings in our study have implications for future practice. The ProQA™ MPDS allows for Emergency Call Handlers to recognise OHCA and facilitates telephone-CPR intervention when required. However, there was a range of time differences noted in

both the interval to recognise cardiac arrest and the delay to commence the first chest compression between studies using the ProQA™ MPDS. Recent changes to the ProQA™ MPDS have enabled quicker recognition and decreased the delay to commence the first chest compression. However, this study recommends further review of the ProQA™ MPDS. In particular, development to ensure a more converged and succinct questioning process to facilitate improved time to recognition and time taken to commence the first chest compression. Early recognition of OHCA by the Emergency Call Handler facilitates early bystander-CPR commencement.

The rapid assessment of the breathing status by Emergency Call Handlers is a key factor in recognising OHCA. The ProQA™ MPDS breathing assessment diagnostic tool (Appendix 6) was initially devised to confirm that breathing is occurring. The breathing diagnostic tool is used to determine the quality and frequency of a patient's breathing pattern whereby the Emergency Call handler can determine a breathing rate through specific questioning. The tool includes a question of "is s/he breathing normally?". If the caller is unsure, the Emergency Call Handler can then ask the caller to say "now" every time the patients takes a breath. This breathing rate is then calculated within the ProQA™ MPDS software by a breathing diagnostic tool which will recommend the commencement of chest compressions if the breathing rate is below a pre-specified threshold. However, Emergency Call Handlers tend to misuse the breathing diagnostic tool to confirm the absence of breathing instead of normal breathing. This delays the time to the provision of the first chest compression (Frazier, 2015).

The distinction between normal and agonal breathing for the layperson is difficult. This lack of distinction has had a direct influence on the Emergency Call Handlers' ability to confidently differentiate between no breathing and agonal breathing, resulting in a difficulty in recognising of OHCA and subsequently commencing chest compressions (Brinkrolf et al., 2018).

The "chain of survival" presented in Figure 1 plays a vital role in reducing the time to commence the first chest compression and is linked to improved survival rates (Lewis et al., 2013) When the first chest compression is initiated in under 120 seconds, survival ratio odds were 8.3 compared to 2.9 when the first chest compression was initiated after two minutes (Van Vleet & Hubble, 2012). This finding is of concern for our study as the median time taken to commence the first chest compression by a bystander was 255

seconds and this is likely to impact on patient survival. This suggests significant room for improvement.

Bystander engagement and willingness to assist in OHCA may potentially increase if Emergency Call Handlers recognise and confirm OHCA and use alternative prompts to facilitate bystander willingness to engage in the process of CPR.

Historical and current use of the ProQA™ MPDS software used in many CCS centres worldwide does not allow for Emergency Call Handlers to deviate from the traditional telephone-CPR guidelines. Emergency Call Handler training is paramount in the proficient use of the ProQA™ MPDS guidelines and being able to recognise the signs of OHCA, including how to differentiate between agonal breathing and normal breathing.

Training regimes identified across the literature remains inconsistent, and the level of training will have a direct impact on the ability of the Emergency Call Handler to recognise OHCA (Hardeland et al., 2017; Meischke et al., 2016). It must be noted that Telephone-CPR procedural compliance is not absolute and may be related to the complexity of the training of Emergency Call Handlers, CPR process and the coaching of such a complex task to bystanders with limited experience (O'Neill & Deakin, 2007). The benefits of ongoing Emergency Call Handler training will help Emergency Call Handlers to remain focused and competent at recognising OHCA and reducing the time taken to commence the first chest compression through ongoing training and simulation (Tanaka et al., 2012). The standardisation of training programs should be consistent and mandatory for any CCS centre using the ProQA™ MPDS. This venture will facilitate consistent procedures and help with improved quality assurance initiatives.

As previously discussed, the use of video in smartphone technology may help support telephone-CPR steps this in the future, enabling the evaluation of the quality of CPR being provided and the initial identification of agonal breathing and other abnormal breathing patterns (Yuksen, Sawatmongkornkul, Tuangsirisup, Sawanyawisuth, & Sittichanbuncha, 2016).

Chapter 6 Conclusion

This study is the first in New Zealand to describe the Emergency Call Handlers' ability to recognise OHCA accurately, measure the key time intervals for the Emergency Call Handler to identify OHCA and initiate telephone-CPR instructions, and for the bystander to commence compressions, and establish the rate of bystander CPR.

This study identified that Emergency Call Handlers had a high sensitivity for recognising OHCA events with 98% of OHCA cases identified. This sensitivity of OHCA recognition was higher than previously published rates. This suggest that that New Zealand based Emergency Call Handlers are skilled at recognising the presence of OHCA while using the ProQA™ MPDS. It may also reflect a trend to improvement in performance over time.

Turning to key time measures, at a median time of 105 seconds (IQR 80-148 seconds) from call pick-up to the recognition of OHCA was identified, this interval exceeded the AHA guideline of 60 seconds. Of interest, many of the studies in the literature review also exceeded the AHA guideline. The median delay from call pick-up to commencement of telephone-CPR instructions was 146 seconds (IQR 110-212 seconds). This interval fell outside of the minimum acceptable standard of less than 120 seconds prescribed by the American Heart Association. This study observed a median delay of 161 seconds (IQR 99-207) from recognition of OHCA to the commencement of the first chest compression. This metric was not reported in the literature reviewed and an AHA guideline was not suggested for this particular timeframe. This timeframe is however of importance as it provides insight into possible reasons for a delay between recognition of OHCA and commencement of chest compressions. The reviewed literature identified the time taken to commence the first chest compression from call pick-up ranged between 176 seconds to 328 seconds. This study identified a median time taken from call pick-up to the first bystander compression of 255 seconds (IQR 201-342). This interval also fell outside of the minimum acceptable standard of less than 180 seconds prescribed by the American Heart Association. These findings suggest that there is considerable room for improvement, both in New Zealand and internationally. Delay to recognition of OHCA and provision of the first chest compressions must be improved in accordance with AHA guidance. This may require a more focused and briefer questioning process to reduce these key time intervals.

Bystander CPR was in progress when the paramedic arrived at the scene in 53% of all the included cases in this study. The rates of bystander-CPR varied widely across the reviewed literature ranging between 22.5% and 81%. In this study, bystander CPR was in progress in 70% of the cases where telephone-CPR instructions were provided and 33% where telephone-CPR instructions were not provided. There was a significant association between the provision of telephone-CPR instructions and the rate of bystander-CPR engagement.

This study reviewed a snapshot of all the OHCA calls received annually. Ideally, it would be useful to capture data for a longer period than the resources for this study allowed.

Recommendations for future research include establishing the specificity of Emergency Call Handler recognition of OHCA, exploring the effects of demographic factors and communication barriers on OHCA recognition, and addressing barriers to commencement of telephone-CPR. Further investigation of the ProQA™ MPDS and non- ProQA™ MPDS dispatch systems on key time intervals is recommended. Lastly, the use of smart technology in OHCA is an emerging field with application to potential to improve recognition of OHCA and the quality of bystander CPR.

There are several implications for practice identified in this study. A review of the ProQA™ MPDS is required to ensure a more converged and succinct questioning process to facilitate improved time to recognition and time taken to commence the first chest compression. Additional Emergency Call Hander training is required to ensure that a distinction between agonal and normal breathing is achieved which will facilitate improved timeframes in the commencement of the first chest compression.

In summary, this study highlights important aspects in the recognition of OHCA, delay to commencement of telephone-CPR instructions and bystander CPR in New Zealand. The links associated with the "chain of survival" remain the foundation for life saving initiatives in OHCA events. By improving performance in these steps we can contribute to improving patient survival.

Glossary of Terms

AHA	American Heart Association
ALS	Advanced Life Support
AMPDS	Advanced Medical Priority Dispatch System
Bystander-CPR	Bystander-cardio-pulmonary-resuscitation
CAD	Computer aided dispatch
CBD	Criteria Based Dispatch®
CCS	Clinical Communication Service
COR	Class of recommendations
CPR	Cardio-pulmonary-resuscitation
CTT	Compression timer tool
ECH	Emergency Call Handler
EMS	Emergency Medical Services
ePRF	Electronic Patient Report Form
LOE	Level of evidence
MTMV	Mouth-to-mouth-ventilation
NPV	Negative Predictive Value
OHCA	Out-of-hospital-cardiac-arrest
PPV	Positive predictive value
PRISMA-P	Preferred Reporting Items for Systematic Review and Meta-Analysis Protocol
ProQA™ MPDS	ProQA™ Medical Priority Dispatch System
STROBE	Strengthening the Reporting of Observational Studies in Epidemiology
Telephone-CPR	Telephone-cardio-pulmonary-resuscitation
TTFC	Time to first compression

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Appendices

Appendix 1 AUT Ethics Committee Approval AUTEC 111/16

27 April 2016

Paul Davey
Faculty of Health and Environmental Sciences

Dear Paul

Re Ethics Application: **16/111 Evaluation of telephone cardio-pulmonary resuscitation instruction in clinical control centres - A New Zealand perspective.**

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

Your ethics application has been approved for three years until 27 April 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.New Zealand/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 27 April 2019;

A brief report on the status of the project using form EA3, which is available online through http://www.aut.ac.New Zealand/researchethics. This report is to be submitted either when the approval expires on 27 April 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.New Zealand.

All the very best with your research,

Kate O'Connor
Executive Secretary
Auckland University of Technology Ethics Committee

Appendix 2 St John Locality Agreement

Date: 13 May 2016

Study title: Evaluation of telephone cardio-pulmonary resuscitation instruction in clinical control centres - A New Zealand perspective.

St John reference: #12

Dear Norm,

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

If possible, it would be good if the researchers were able to consider the potential of impact of patient ethnicity on the time taken to identify cardiac arrest and initiate CPR instructions.

Yours sincerely

Dr Bridget Dicker, PhD
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Appendix 3 Literature Review Key Findings

	Authors	Sample size	Study design/protocol	Key findings
1	Dami, Fuchs, et al. (2010)	n=497	A prospective study whereby dispatchers given new procedures to provide telephone-CPR. All call recordings were reviewed by the medical director	Dispatchers proposed telephone-CPR in 69% of eligible cases. All dispatchers were healthcare professionals. 8% of cases did not require telephone-CPR instruction. telephone-CPR instruction developed without MPDS or CBD systems.
2	F. Dami et al. (2015)	n=1679	A prospective review of all dispatch audio recordings. Ability to recognise cardiac arrest was established. Timing was recorded. Provision of bystander-CPR was recorded accordingly	Emergency Call Handler correctly identified 71% of OHCA and 84% of cases in which they were able to assess consciousness and breathing. Mean time to commencement of chest compressions was 220s. The criteria-based software is similar to MPDS in time to CPR and recognition of OHCA. Agonal breathing recognition remains the weakest link across both dispatch systems.
3	Deakin et al. (2010)	n=42	Retrospective Observational review of digital recordings of all paediatric OHCA. PRFs were then reviewed to confirm diagnosis of OHCA	Delays in commencing CPR median time of 3 minutes to first breath, 4 minutes to first compression. Possibly due to time spent to establish an address. Counting out load found to improve CPR compression rates. Panic remains a concern and the greatest cause of delay in delivering CPR. This is with the use of the MPDS. This did not discuss ability to recognise cardiac arrest.
4	Hardeland et al. (2014)	n=414	Observational study of confirmed EMS adult OHCA calls. Digitised recordings were audited to evaluate protocol compliance, OHCA recognition and provision of pre-arrival instructions.	MPDS vs CBD showed recognition of OHCA of 82% and 77% respectively. telephone-CPR offered in 81% and 74% respectively. Time to chest compression 4.3 min vs 3.7 min respectively. CBD offered faster and more frequent telephone-CPR. telephone-CPR delayed 3-4min in both systems.
5	Lewis et al. (2013)	n= 476	A retrospective cohort study of out-of-hospital cardiac arrests (OHCA). This	Dispatchers recognised cardiac arrest in 80%. 13% of cases could not assess consciousness and breathing. In this circumstance, if these were excluded the recognition rate would be 92%. Emergency Call Handlers less like to recognise OHCA when witnessed and bystander-CPR less likely to be provided when dispatcher did not recognise (p=0.001) Time to first compression =176s, median time to

				recognition = 75s. telephone-CPR resulted in bystander-CPR rate of 62%.
6	Moller et al. (2016)	n=643	An observational study collecting data from cardiac arrest database. Data was compared to findings recorded within the emergency control centre. Missing calls were further analysed by recordings using a uniform data template	Ability to recognise OHCA varies as a result of methodology, training, competence and dispatch tools. The recognition of OHCA was comparable however the data collection was inconsistent regardless of the same dispatch tool being used.
7	Nuno et al. (2017)	n=3398	Observational cohort study of all suspected OHCA calls	87.4s noted to recognise OHCA however in language barriers it was 160.6s. 144.4s to start CPR and 231.3s with a language barrier. OHCA recognised in 90-100% of the cohort. Chest compressions were started in 47-59%. Time to recognise was 87s, call to first compression was median of 174s.
8	Oman and Bury (2016)	n=202	A retrospective review of all OHCA in a two-year period. All audio, patient report forms. Time from call receipt to first compression was noted	Median time to first compression was 5min 28s. Average of 285s using MPDS. 124s reported in a simplified version. Time delays are too long due to perform a patient assessment and obtaining victim address. MPDS sequence needs to be adjusted beginning CPR ASAP which are more focused.
9	Stipulante et al. (2014)	n=1569	Retrospective and prospective observational review and assessment of patients of OHCA pre- and post-implementation of an intervention to help ensure that bystanders initiate CPR	Non-MPDS. Create their own version called ALERT system. Agonal breathing played a role in the failure to recognise OHCA. An increase on bystander-CPR was noted regardless of its underutilisation. OHCA recognition occurred in 82%and 75% of the calls.

10	C. Vaillancourt et al. (2015)	n=2260	A multi-centre prospective cohort study of adult OHCA not witnessed by EMS and for which resuscitation was attempted.	66% of OHCA successfully identified. 21% of patients were shown to not be in cardiac arrest and 11% (2.4% of all cases) of these received chest compression inappropriately. MPDS not used and Dispatch Priority Card Index system was developed locally to assist dispatchers. Time to first compression was not reported. Chest compression only CPR was provided.
11	Van Vleet and Hubble (2012)	n=778	Retrospective review of data recorded for all OHCA. Only cases identified by Emergency Call Handlers and who received telephone-CPR instructions were included in the study.	Time to first compression was recoded across three versions of MPDS as a mean of 240s. CPR initiated after 4min of collapse is associated with poor outcomes. It was found in other studies that time to first compression improved substantially when mouth to mouth was removed from the instruction.

Appendix 4 Audit Form

EMEREGENCY CALL HANDLER CPR INSTRUCTION AUDIT

Incident date: ________ Patient Age and Gender: ____________

Incident #: ________ Cardiac Arrest Location: _____________

1. **Dispatcher recognised the need for CPR?** ☐ **Yes** ☐ **No**
2. **CPR Instructions given?** ☐ **Yes** ☐ **No**

Time of call	Time - taken to recognise need for CPR	Time – began instructions	Time – of First Compression	Time: of first breath (if applicable)
___:___:___	___:___:___	___:___:___	___:___:___	___:___:___

3. **Patient Disposition**

Patient Conscious?	Patient Breathing Normally?	Suspected Agonal Breathing Reported or Heard?	CPR already in Progress / Performed?
Yes ☐	Yes ☐	Yes ☐	Yes ☐
No ☐	No ☐	No ☐	No ☐
Unknown ☐	Unknown ☐	Unknown ☐	Unknown ☐

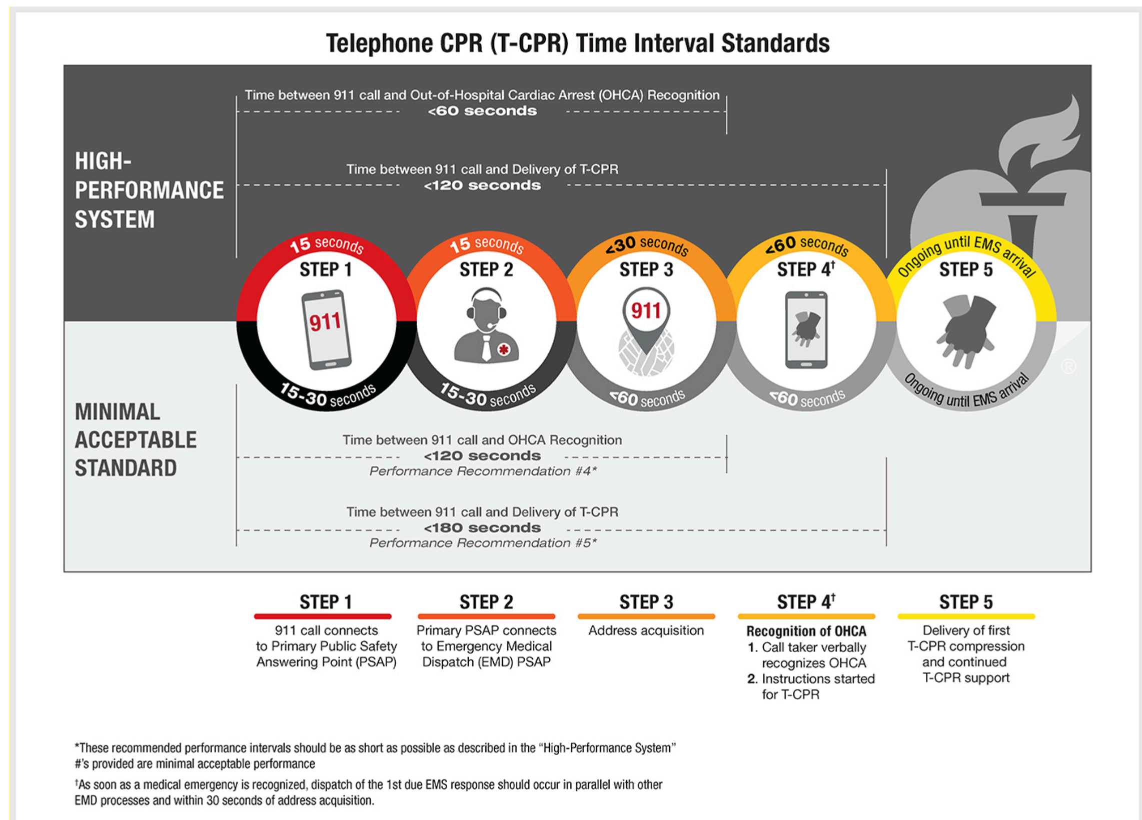
4. **CPR Instruction Specifics:**

Hand location given?	Compression Rate given?	Compression Rate counted?	Compression depth given?
Yes ☐	Yes ☐	Yes ☐	Yes ☐
No ☐	No ☐	No ☐	No ☐

5. **If CPR instructions not given, tick all that apply:**

- CPR already in progress
- Someone at the scene knew CPR
- Patient did not present in cardiac arrest
- Patient was dead on arrival
- Do not resuscitate order (DNR)
- Communication lost
- Rescuer refused to assist
- Rescuer physical limitations
- Rescuer too emotional to assist
- Call handler did not recognise cardiac arrest
- Call handler delay – AMPDS not followed
- Other call handler issues
- Other:

Appendix 5 Telephone-CPR time interval standards



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https://cpr.heart.org/en/resuscitation-science/telephone-cpr/t-cpr-recommendations-and-performance-measures

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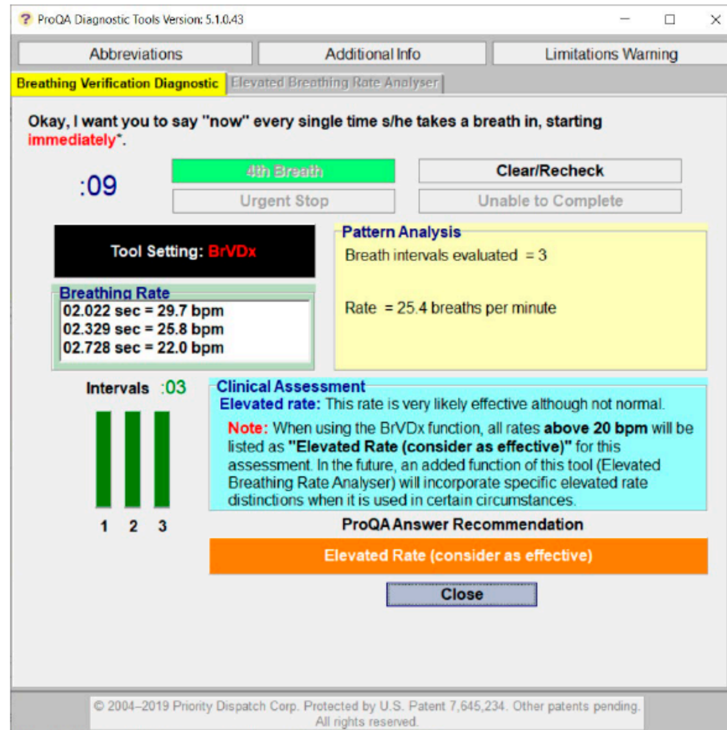
Appendix 6 ProQA™ Breathing Diagnostic tool



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Appendix 7 Case entry log

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Appendix 8 CPR instruction tool

C — AIRWAY / ARREST / CHOKING (UNCONSCIOUS) – ADULT ≥ 8 YRS — ADULT

1 (Phone to Patient)

If there is a **defibrillator** (AED) available, **send** someone to get it **now**, and **tell me** when you **have it**.

• Are you **right by** her/him **now**?

Yes → 2

(No) **Get** the **phone** as **close** to her/him as possible. Don't hang up. **Do it now** and tell me when it's done. (If I'm not here, stay on the line.)

→ 2

2 Position Patient

Listen carefully.

(Not breathing) **Lay** her/him **flat** on her/his **back** on the **floor/ground** and **remove** any **pillows**.

(Breathing) **Lay** her/him **flat** on her/his **back** and **remove** any **pillows**.

(3rd TRIMESTER) **Lay** her on her **left side** (on **the floor/ground if not breathing**) and **wedge a pillow** behind her lower back.

Not Breathing/AGONAL/UNCERTAIN → 4

Breathing → 3

3 Check Breathing

Now place your **hand** on her/his **forehead**, your **other hand** under her/his **neck**, then **tilt** the head **back**.

Put your **ear** next to her/his **mouth**.

• Can you **feel** or **hear** any breathing?

No → 4

UNCERTAIN/Just a little → 4

Yes → 17

4 Pathway Director

* **Select the most appropriate pathway below:**

Ventilations (V) 1st → 5

(if any of these conditions apply)

Allergic reaction — **Overdose/Poisoning**
Asthma/COAD — **Severe trauma**
Drowning — **Strangulation**
Hanging — **Suffocation**
Lightning strike — **Toxic inhalation**

Compressions only | Compressions (C) 1st → 6

Any other problems *(if none of the above apply)*

Unconscious Choking (UC) → 6

5 Start Mouth-to-Mouth

I'm going to tell you how to give **mouth-to-mouth.***

*Refused M-T-M → 6/10

(Place your **hand** on her/his **forehead**, your **other hand** under her/his **neck**, then **tilt** the head **back**.) Now **pinch** her/his **nose** closed and completely **cover** her/his **mouth** with **your mouth**, then blow **2 regular breaths** into the lungs, about **1 second** each. The chest should **rise with each breath**.

• Did you **feel** the air going in and out?

Yes → 1st cycle of CPR → 6; Continuing CPR → 9

No → V 1st → 13; C 1st → 10; UC → 9

6 CPR Landmarks

Listen carefully and I'll tell you how to do resuscitation.

(Not 3rd TRIMESTER) (Make sure s/he is **flat** on her/his **back** on the **floor/ground**.)

Place the **heel** of your **hand** on the **breastbone** (in the **centre** of the chest), right **between** the nipples.

Put your **other hand** on **top** of that hand.

V 1st → 7

C only | C 1st → 11

UC → 7

V 1st & Refused M-T-M → 11

7 CPR (Ventilations 1st/UC)

Pump the chest **hard and fast 30 times**, at least **twice per second** and **5 cm** (2 inches) deep. Let the chest **come all the way up** between pumps. Tell me when you're done.

(Previous airway blockage) **Check** in her/his **mouth** for an **object** and **remove** anything you find.

• Do you **understand** me so far?

Yes → 8; UC → 5

No → Clarify/Reassure

8 Continue CPR plus Mouth-to-Mouth

With your hand **under** her/his neck, **pinch** her/his **nose** closed and **tilt** her/his head **back** again.

Give **2 more regular breaths**, then **pump** the chest **30 more times**.

Make sure the **heel** of your **hand** is on the **breastbone** (in the **centre** of the chest), right **between** the nipples.

• Do you **understand**?

Yes → 9

No → Clarify/Reassure

9 Continue CPR

C only | Refused/Unsuccessful M-T-M → 10

* If M-T-M instructions **have not yet been provided**, link to **Panel 5**.

From now on, **give** her/him:

(V 1st) or (UC) — **2 breaths** then **30 pumps**, **2 breaths** then **30 pumps**.

(C 1st) — **100 pumps** then **2 breaths**, **100 pumps** then **2 breaths**.

→ 10

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Appendix 9 International Academy of Emergency Dispatch – Copyright approval

IAED
International Academies of Emergency Dispatch

September 27, 2019

Mr. Norm Wilkinson
Lecturer, Paramedicine
Auckland University of Technology

Re: Permitted Use of Intellectual Property

Dear Mr. Wilkinson,

On behalf of the International Academies of Emergency Dispatch (the "IAED"), I am pleased to allow you to use certain information and materials contained within the IAED's Medical Priority Dispatch System (the "MPDS") for the limited, academic purpose of presenting your master's degree thesis. Accordingly, the IAED grants you the use of the previously provided images of ANZ MPDS v13 Case Entry, Protocol C panels 1-9, and the Breathing Verification Diagnostic (altogether the "Intellectual Property").

The approval for use of the Intellectual Property is contingent upon your agreement with the following conditions. It is agreed that you may not alter, modify, distribute nor publicly display, any part of the Intellectual Property other than as allowed herein. You may not allow others to use the Intellectual Property and in the event you refer or quote directly from the materials in your thesis, you agree to include the following acknowledgement: "**© 2019 IAED. All Rights Reserved. Used by permission of the International Academies of Emergency Dispatch.**"

It is further understood that the IAED reserves the right to revoke the use of its Intellectual Property at any time and for any reason.

Kind regards,

Pam Stewart

Pam Stewart
Director of Operations

SETTING THE STANDARD FOR EMERGENCY DISPATCH WORLDWIDE

40 YEARS 1979 2019
PRIORITY DISPATCH SYSTEMS
PROTOCOLS

Appendix 10 American Heart Association Print Copyright Agreement

Inv #15381-NWILKINSON

September 17, 2019

PRINT COPYRIGHT USE AGREEMENT

Norm Wilkinson
Auckland University of Technology
60 Arran Rd., Browns Bay
Auckland 0630
NEW ZEALAND

Dear Mr. Wilkinson:

Amount Due: **$330.00 U.S. FUNDS (WAIVED)** This is a fee for service and not a charitable contribution). Our tax id number is 13-5613797. **Please consider this letter an invoice.**

Approval of this request is contingent upon receipt of a $330.00 U.S Funds (WAIVED) processing fee and a signed copy of this Agreement (including Exhibit A.) Please send a check (drawn on a U.S. Bank or an international money order) payable to the American Heart Association with a copy of this Agreement to PO Box 841750, Dallas, Texas, 75284-1750. Bank transfer or credit card payment information will be provided upon request.

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Signature of Requestor__________ __________

Printed Name____ Norman A Wilkinson ____

Date____ 04/08/2019 ____

EXHIBIT A

Publication Name – Circulation.2017;137:e7-e13
2017 American Heart Association Focused Update on Adult Basic Life Support and Cardiopulmonary Resuscitation Quality

Specifically:
Page e8, Table. ACC/AHA Recommendation System: Applying Class of Recommendation and Level of Evidence to Clinical Strategies, Interventions, Treatments, or Diagnostic Testing in Patient Care* (Updated August 2015)

Citation/Credit Line:

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Circulation.2017;137:e7-e13
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Publication Name – cpr.heart.org

Specifically:
Image of Performance Measures: Telephone CPR (T-CPR) Time Interval Standards @ https://cpr.heart.org/en/resuscitation-science/telephone-cpr/t-cpr-recommendations-and-performance-measures

Citation/Credit Line:

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For Use In:

a print only version of the above referenced material will be used as part of the student's doctoral project titled "Evaluation of Telephone Cardio-Pulmonary Resuscitation Instructions in Ambulance Clinical Communication Centres – A New Zealand Perspective.

NOTE: If the student decides at a later date to publish the paper/AHA material, the request **must** be submitted to the AHA for review/approval before the AHA material is published.