The effect of paramedic position on external chest compression quality: A simulation study

Paul Davey

PG Dip HSc in Applied Ethics, PG Dip HealSc in Resuscitation, PG Cert Ed

BHSc in Paramedicine.

A thesis submitted to the Auckland University of Technology in fulfilment of the requirements of the degree of
Master of Philosophy AK3720

2014

School of Clinical Sciences

Department of Paramedicine

TABLE OF CONTENTS

LIST OF FIGURES

LIST OF TABLES

ATTESTATION OF AUTHORSHIP

I hereby declare that this submission is my own work and that, to the best of my knowledge and belief, it contains no material previously published or written by another person 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.

Chapters 2 to 4 of this thesis form the basis of three papers that have been submitted to peer-reviewed journals for consideration for publication. Chapter 3 has had two abstracts and Chapter 4 has had one abstract accepted for the New Zealand Resuscitation Council Conference: Science to Sensibility Conference (24-26 July 2014). Chapter 4 also had an abstract accepted for the Paramedics Australasia International Research Conference (Canberra October 2013) which won the best scientific poster award and has been published in the Australasian Journal of Paramedicine.

My contribution and the contribution by the various co-authors to each of these papers are outlined at the beginning of the thesis. All co-authors have approved the inclusion of the joint work in this master's thesis.

Paul Davey
September 2014

CANDIDATE CONTRIBUTIONS TO CO-AUTHORED PUBLICATIONS AND CONFERENCE PRESENTATIONS

Chapter 2

Davey, P., Dicker, B. & Whatman, C. Over-the-head or from-the-side; does position make a difference to the quality of cardiopulmonary resuscitation? A review of the literature. Submitted to *Resuscitation* 26th June ref RESUS-D-14-00553	Davey Dicker Whatman	80% 10% 10%

Chapter 3.

Davey, P., Dicker, B. & Whatman, C. Comparison of chest compressions metrics measured using the Laerdal Skill Reporter and Q-CPR: A simulation study y. Submitted to *Simulation in Healthcare* 31st August ref SIH-D-00171	Davey Dicker Whatman	80% 10% 10%
Davey, P., Dicker, B. & Whatman, C. (2014) The frequency of leaning and its association with depth of compression measurement during simulated CPR. Abstract accepted at the New Zealand Resuscitation Conference 2014 (Poster Presentation)	Davey Dicker Whatman	80% 10% 10%
Davey, P., Dicker, B. & Whatman, C. (2014) Comparison of external chest compressions using Laerdal Skill Reporter and Q-CPR. A manikin study. Abstract accepted at the New Zealand Resuscitation Conference 2014 (Poster Presentation)	Davey Dicker Whatman	80% 10% 10%

Chapter 4.

Davey, P., Dicker, B. & Whatman, C. Title: The Paramedic position, over-the-head or from-the-side, does not influence the quality of cardiopulmonary resuscitation. Submitted to *Resuscitation* 30th August ref RESUS-D-14-00687	Davey Dicker Whatman	80% 10% 10%
Davey, P., Whatman, C. & Dicker B. (2014). The effect of paramedic position on external chest compression quality. A simulation study. Abstract accepted for the Paramedics Australasia International Research Conference Canberra October 2013. (Poster) - Awarded Best Scientific Poster	Davey Dicker Whatman	80% 10% 10%
Davey, P., Whatman, C. & Dicker B. (2014). The effect of paramedic position on external chest compression quality. A simulation study (Abstract). *Australasian Journal of Paramedicine, 11*(1), 16.	Davey Dicker Whatman	80% 10% 10%
Davey, P., Dicker, B. & Whatman, C. (2014) Does the position of the paramedic performing chest compressions during a simulated cardiac arrest influence compliance with the 2010 guidelines? Abstract accepted for the New Zealand Resuscitation Conference 2014 (Oral)	Davey Dicker Whatman	80% 10% 10%

Paul Davey   Dr Bridget Dicker   Dr Chris Whatman

ACKNOWLEDGEMENT

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

- Tineke Water for her leadership in the fields of ethics and research within the School of Health Care Practice.
- Jane Koziol-McLain for her time and expert critique of my research proposal.
- Patria Hume for guidance and poster critique.
- Naumai Smith and Peter Larmer for their leadership and support.
- The Paramedicine and Emergency Management Team for their support, protection of my writing time and ongoing encouragement.
- Priya Parmar who provided biostatistical expertise.
- The St John paramedics for their generosity and participation.

Finally, most importantly, I would like to acknowledge the support of my family: Pip, Emma, Max, Michael and Aidan, for their support, without which this journey would not have been possible.

ETHICAL APPROVAL

Ethical approval for this research was sought and granted by the Auckland University of Technology Ethics Committee (AUTEC). Approval granted on 4th of February 2013 by AUTEC, the reference was 13/10 covering the period from the 4th of February 2013 to the 5th of February 2016.

Locality review and approval was also sought from St John. St John approved the study on the 18th of April 2013; reference 009.

ABSTRACT

Out-of-hospital cardiac arrest (OHCA) is a globally important public health issue that continues to be a significant cause of premature death. The incidence of OHCA treated by Emergency Medical Services (EMS) is around 50 to 55/100,000 per person-years across the US, Canada, Australia and New Zealand. There is significant disparity in the rates of survival to hospital discharge from OHCA. For OHCA treated by EMS this rate can vary as much as 1% to 31%.

In order to improve outcomes for cardiac arrests the International Liaison Committee on Resuscitation (ILCOR) aims to integrate resuscitation science with real world clinical practice. ILCOR states there is a need to develop a culture of high quality resuscitation using a quality improvement approach. Survival from cardiac arrest is a complex issue with many stakeholders that form the basis of a system of care. ILCOR proposes that individual performance needs to be evaluated so that participants within the system of care are informed and can therefore effectively intervene to improve care

Paramedics are the primary treatment providers for OHCA. Recently the resuscitation guidelines, which paramedics use in their practice, have emphasised the performance of quality chest compressions. With this in mind this thesis sought to investigate whether the position of the paramedic performing chest compressions, either from-the-side (FTS) or over-the-head (OTH), influenced the quality of cardiopulmonary resuscitation (CPR). A review literature identified only a few small studies in which OTH CPR was investigated over short durations. There was heterogeneity in the study design, types of participants and quality metrics measured with inconsistencies in the results across the studies. All of the studies identified in the review were manikin studies that used manikin-based technology, such as the Laerdal Skill Reporter (LSR), to measure the quality of CPR. Subsequent to these studies defibrillator technology has evolved and now devices that can measure CPR quality have been integrated into the defibrillator, an example of which is Q-CPR® associated with the MRx

defibrillator. Such devices enable measurement of CPR quality in both manikin and human studies.

The first study (Chapter 3) investigated if the new defibrillator technology could be used to measure CPR quality in a manikin study. This study compared the measurement of CPR quality metrics simultaneously using LSR and Q-CPR®, for chest compression performed OTH and FTS. The principle finding of this study was that there is no significant difference in the majority of chest compression quality metrics measured between the LSR and the Q-CPR® devices. However, there were significant differences in the measurement of duty cycle and also the depth of compressions between the two devices. The mean difference in the depth of compression was observed to increase with an increasing incidence of leaning. The conclusion was that Q-CPR® is a suitable alternative to LSR for measurement of the CPR quality and thus it was used in the main study.

The main study compared OTH and FTS CPR quality (performed by 30 paramedics) during two simulated cardiac arrest scenarios, each of approximately 25 minutes duration. There was no significant difference in mean CPR quality between compressions performed OTH or FTS for all metrics measured. We concluded that for two rescuer CPR the composite technique, where the paramedic that is positioned at the head of the manikin performs OTH CPR, is an effective alternative to the traditional method of only performing CPR FTS.

CHAPTER 1

INTRODUCTION AND RATIONALE (PREFACE)

Background

The incidence of out-of-hospital cardiac arrest (OHCA) treated by emergency medical services (EMS) in the US and Canada is estimated to be in the range of 50 to 55 per 100,000 person-years (Travers et al, 2010). Whilst there is substantial variability in the incidence of out-of-hospital cardiac arrest attended by EMS between countries (17-128 per 100,000 person-years) there is agreement that sudden death due to cardiac arrest carries a tremendous social burden and economic impact (Berdowski, Berg, Tijssen, & Koster, 2010; Grasner & Bossaert, 2013). The annual worldwide estimate of sudden cardiac arrest is a staggering 4 to 5 million cases per year with coronary artery disease as an aetiology contributing to 80% of the cases in the general population (Chugh et al., 2008).

There is a dearth of New Zealand published data pertaining to out-of-hospital cardiac arrest incidence and survival. Crone (1995) reported the incidence of EMS treated OHCA as being approximately 42 per 100,000 person-years with a survival to hospital discharge rate of 13% (Crone, 1995). More recently a small Wellington study has shown an EMS treated OHCA rate of 36 per 100,000 person-years survival to hospital discharge rate of 12% (Robinson, Swain, Hoyle, & Larsen, 2010). Despite increased availability of defibrillators and changes to resuscitation guidelines, the two small New Zealand studies would suggest that there has been no demonstrable improvement in survival from OHCA over the past decade. Travers et al (2010) reports that internationally cardiac arrest survival rates vary between locations and that these inequities have persisted over decades.

Survival from cardiac arrest is dependent upon multiple factors and is difficult to prognosticate the outcome (Nolan et al., 2008; Rossetti & Koenig, 2011). Some of the factors identified as influencing survival and outcome from OHCA include the complexities of the patient's comorbidities, aetiology, location of cardiac arrest, whether the cardiac arrest was witnessed, early CPR and early defibrillation, quality of CPR, effective advanced life support and integrated post-cardiac arrest care. These principles are depicted by the Chain of Survival which has five links, Figure 1. The links of the chain are: Immediate recognition and activation, early CPR, rapid defibrillation, effective advanced life support and integrated post-cardiac arrest care (Travers, et al., 2010).

Figure 1. The Chain of Survival

Reprinted with permission 2010 American Heart Association Guidelines for CPR & ECC Part 4: CPR Overview Circulation.2010;122(suppl 3): S676-S684 ©2010, American Heart Association, Inc

The International Liaison Committee on Resuscitation (ILCOR) published the 2010 International Consensus on Cardiopulmonary Resuscitation and Emergency Cardiovascular Care Science with Treatment Recommendations Guidelines (2010 Guidelines). These guidelines are adopted internationally as best practice guidelines by various Resuscitation Councils. A key feature of the 2010 Guidelines is the increased emphasis on the quality of chest compressions and a de-emphasis on ventilation as a part of the cardiopulmonary resuscitation (CPR) care bundle. This focus is underpinned by multiple studies identifying poor external chest compression (ECC) quality observed in both in-hospital and out-of-hospital cardiac arrests (Abella et al., 2005; Wang, Simeone, Weaver, & Callaway, 2009; Wik et al., 2005). The fundamental elements of adult ECC quality include providing chest compressions of an adequate rate (>100 per minute), adequate depth (> 50mm), allowing complete chest recoil (hand release or avoiding lean) and minimising interruptions in compressions (Travers et al, 2010).

The American Heart Association, in a consensus statement, describes poor quality CPR as being a preventable harm, further commenting that the current disparity in the quality of cardiopulmonary resuscitation (CPR) provided by health clinicians is significant and unacceptable, resulting in preventable death (Meaney et al., 2013). The heterogeneity of CPR performance is not limited to in-hospital cardiac arrests. The performance of CPR during out-of-hospital cardiac arrest has also been reported as being substandard with one study demonstrating large periods of time where compressions were not occurring and having a shallow mean compression depth (Wik, et al., 2005).

In light of the significant burden posed by cardiac arrest and the increased emphasis of improving the quality of ECC there is a need to reevaluate cardiac arrest management practices and performance. During CPR, standard ECC is performed from-the-side. In the pre-hospital environment the norm is for a responding ambulance to have a crew of two rescuers (paramedics). Paramedics commonly perform external chest compressions from-the-side (FTS) and/or from over-the-head (OTH); with OTH being utilised by one paramedic to facilitate other interventions such as establishing intravenous access and administering pharmaceutical agents by the second paramedic. Only a few studies have investigated the use of the OTH position for performing ECC prior to the introduction of the 2010 Guidelines (Bollig, Steen, & Wik, 2007; Handley & Handley, 2004; Perkins, Stephenson, Smith, & Gao, 2004).

These previous studies have several limitations (Bollig, et al., 2007; Handley & Handley, 2004; Perkins, et al., 2004). The first is that the manikin and defibrillator technology have evolved – no studies have used Q-CPR® which is a biometric feedback tool that is now available as a part of the defibrillator for use within the ambulance and other clinical settings (use of the Q-CPR® enables the study design to be replicated in a human trial with the same measurement tool). Secondly, most of the studies did not have working paramedics as participants. Paramedics, as the primary treatment providers for OHCA, are most likely to be familiar with and would use the OTH position to perform chest compressions. Most studies used students (medical and paramedic), firefighters or nurses with little clinical experience of management of OHCA.

Another limitation of the previous studies was the length of time that chest compressions were conducted; most studies choosing to evaluate two minutes of CPR. Two minutes represents the approximate length of one cycle of CPR, generally CPR is performed for a longer period. A time period for performing CPR of 20 to 30 minutes would more closely represent the clinical management time frame for a typical OHCA. The National Association of EMS Physicians propose that resuscitation efforts can be terminated in OHCA patients who do not respond to at least 20 minutes of Advanced Life Support care (Bailey, Wydro, & Cone, 2000; Morrison et al., 2010). Likewise most of the studies had a study protocol involving a single rescuer performing CPR whereas the standard crewing of an urban response EMS ambulance includes a crew of two paramedics

There was also substantial heterogeneity in the airway adjunct used, ventilation device used, inclusion of defibrillation and the resuscitation guidelines utilised across the previous studies. The current study is occurring two years after the introduction of the 2010 Guidelines which has a significant focus and a greater emphasis on quality external chest compressions than previously published guidelines–the ‘push hard and fast’ campaign (Koster et al., 2010; Travers, et al., 2010).

Given the limitations of previous work the aim of this study was to determine if there is a difference in the quality of CPR between OTH and FTS positions for the delivery of ECC by a crew of two paramedics subsequent to the introduction of the 2010 Resuscitation Guidelines. The CPR quality metrics that were analysed included chest compression rate, compression depth, rescuer leaning, ventilation rate, no-flow time, perishock pauses and chest compression fraction. In addition the effect of fatigue on quality CPR metrics and relationships between compression depth, rate of compression and paramedic demographics are discussed.

Structure of the thesis

This thesis is composed of a total of five chapters (Figure 2) with the final chapter being a culmination or synopsis of the discussion and conclusions.

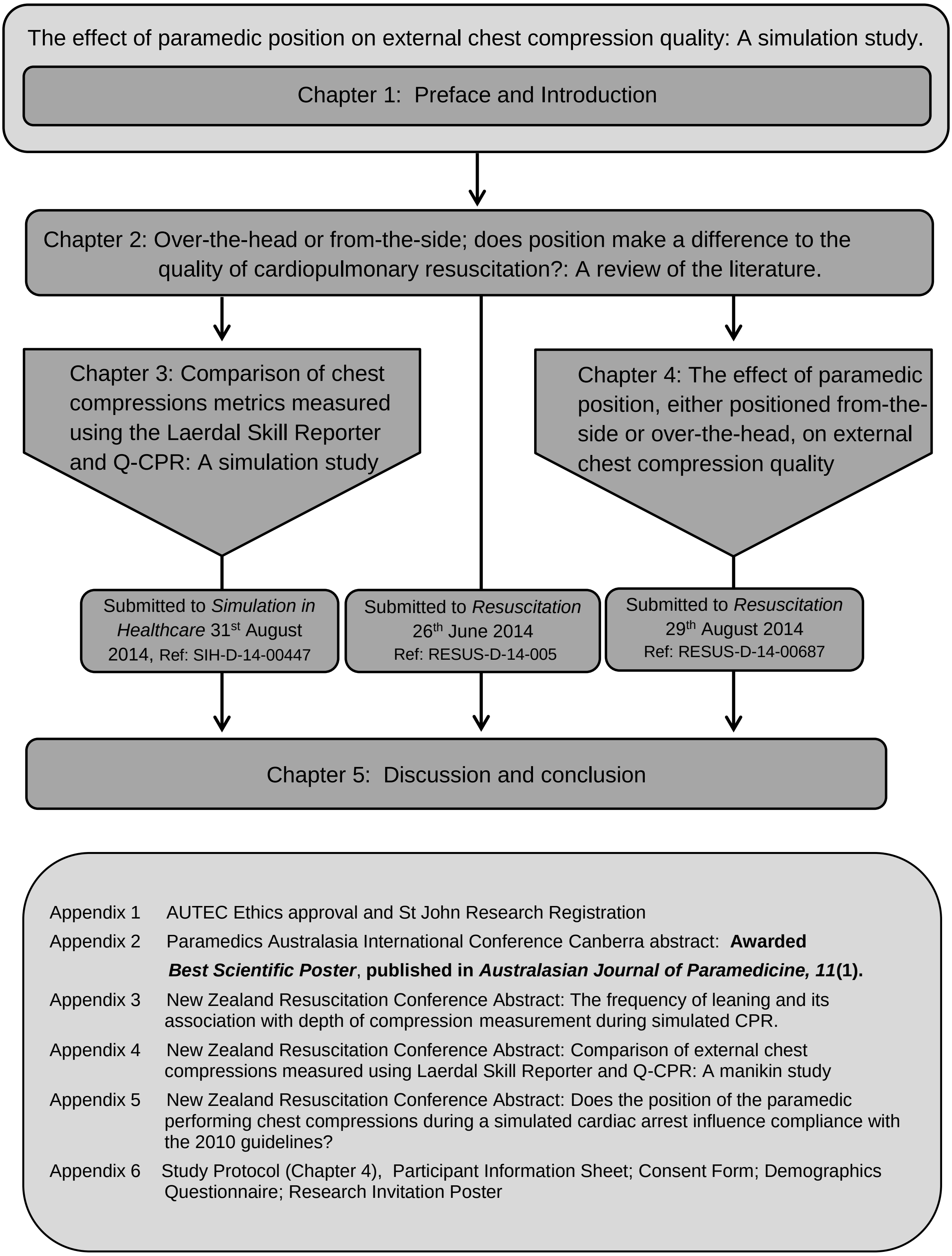


Figure 2: Overview of thesis chapters.

Chapters 2, 3 and 4 have been written with a view of submission for publication in journals and, as a consequence, there is a degree of repetition in the introduction and methods sections. Two experimental studies form the basis of this thesis. Both studies have been presented at international and national conferences, the peer feedback from which has helped shape and improve the chapters. The Auckland University of Technology dictates that for a thesis the reference list must be included as one terminal collated list at the end of the final chapter. Hence a reference list has not been included with each chapter.

Chapter 2 is a review of the literature. This review is a systematic review of the literature that focuses on comparing the delivery of chest compressions performed from-the-side (standard position) to those performed over-the-head. The review was limited to the date period of 2000 to 2013, during which three Resuscitation Guidelines were published (2000, 2005 and 2010), for the ease of comparison. The heterogeneity and low number of studies identified for review make it difficult to conclusively determine the utility of using OTH CPR. There is some evidence that, in manikin studies at least, chest compressions performed OTH may result in a similar quality of CPR when compared to chest compressions performed FTS over a short time period. As no human randomised controlled trials have been conducted it is not possible to conclusively comment on the translation of this finding to clinical practice.

Chapter 3 informs the utility of using Q-CPR® as an appropriate measurement tool of chest compression quality metrics in the main study (Chapter 4). The traditional method of measuring chest compression quality during a simulated cardiac arrest is to use manikin-based sensors and computer based analysis software, the Laerdal Skill Reporter (LSR). This chapter compares chest compression data from the manikin-based LSR technology to the puck-based Q-CPR® technology during chest compressions on a Resusci Anne®Simulator manikin. This informed the suitability of using Q-CPR® technology for assessing paramedic chest compression performance during CPR.

The main study is described in chapter 4 in which Q-CPR® is used to measure and compare chest compression quality between chest compressions performed from-the-side and over-the-head. A standardised cardiac arrest simulation using the Resusci Anne® manikin was used. Paramedics (n=30) were paired and randomised so that one performed over-the-head compressions and the other from-the-side for the duration of the simulation. The paramedic performing chest compressions alternated every cycle, stopping after a total of ten cycles. After a ten minute rest period the paramedics crossed over positions and repeated the simulation. This protocol allowed direct comparison of CPR performance for the participants in each position. The quality of CPR was measured using Q-CPR® with audio-visual feedback disabled.

Additionally in chapter 4 the effect of paramedic position on other aspects of CPR such as perishock pauses, fatigue of the paramedic over time and ventilation rate are investigated. Also, relationships between compression depth, rate of compression and paramedic demographics are discussed.

Finally in Chapter 5 the key findings from the research are summarised with limitations and opportunities for future research discussed.

CHAPTER 2

OVER-THE-HEAD OR FROM-THE-SIDE; DOES POSITION MAKE A DIFFERENCE TO THE QUALITY OF CARDIOPULMONARY RESUSCITATION? A REVIEW OF THE LITERATURE

Overview

A literature review was conducted to examine whether there is a difference in the quality of cardiopulmonary resuscitation (CPR) when chest compressions are performed from-the-side (FTS) or over-the-head (OTH).

Methods: The Electronic databases Cochrane, Medline, CINAHL, Scopus and Biomedical Reference collection (OVID and EBSCO) were searched using the key terms “over-the-head” OR “over-the-head” AND “CPR’ OR “cardiopulmonary resuscitation”. Articles describing over-the-head CPR were eligible for inclusion. Limits included language (English), full text journal articles and date of publication (2000 to 2014). The date range limited the number of Resuscitation Guidelines to three for ease of comparison.

Results: The search identified a total of 138 potentially relevant papers. After exclusion based on date, English language, full text and duplicates a total of 13 articles appeared relevant. After reviewing the abstracts a further five articles were excluded leaving eight articles for full review. There were no randomised controlled trials, or meta-analyses of such (LOE 1). Likewise no LOE 2, LOE 3 or LOE 4 studies were identified. All of the eight studies reviewed were LOE 5 manikin studies. Seven studies reported similar CPR quality between OTH and FTS CPR. Two studies compared two-rescuer FTS CPR to single-rescuer OTH CPR; one reported no difference in CPR quality, conversely the other reported inferior CPR quality with OTH CPR.

Conclusion: The heterogeneity and low number of studies identified for review make it difficult to conclusively determine the utility of using OTH CPR. However, in the manikin studies reviewed, chest compressions performed OTH demonstrated a similar quality of CPR when compared to chest compressions performed FTS over a short time period. As no human randomised controlled trials have been conducted it is not possible to comment on the translation of this finding to clinical practice. Further studies are needed.

Introduction

The 2010 American Heart Association Guidelines for Cardiopulmonary Resuscitation and Emergency Cardiovascular Care (2010 Guidelines) have emphasised that effective chest compressions are fundamental to cardiac arrest management (Travers, et al., 2010). These guidelines instruct to push hard and fast, minimising interruptions in performing chest compressions and advise that all people who perform CPR should focus on high quality CPR delivery. Five metrics of high performance CPR have been identified based on the influence that these metrics have on both blood flow and outcome, Table 1 (Travers et al., 2010).

Table 1. Metrics of high quality cardiopulmonary resuscitation (Adult)

	Performance standard
Chest compression fraction	CCF > 80% - minimise interruptions
Chest compression rate	≥ 100/minute (100 – 120/minute)
Chest compression depth	≥ 50mm
Chest recoil (residual leaning)	Leaning should be minimised / avoided
Ventilation	< 12 breaths/minute (8-10/min with advanced airway used

Other metrics of quality CPR have been suggested to ensure uniform reporting to facilitate analysis and comparison. These include time and chest compression fraction, which represents the time during the resuscitation that compressions are or are not being performed, pauses associated with the pre- and post-shock periods, the fraction of minutes that compression depth was less than 38mm, the fraction of minutes with compression rates less than 90 or greater than 120 per minute, the fraction of minutes with no ventilation, ventilation rates greater than 25 per minute and the duty cycle. The duty cycle is the proportion of the time that there is active pressure on the chest, representing the down stroke of compression and should be less than 50% (Kramer-Johansen, Edelson, Losert, Kohler, & Abella, 2007).

In light of the significant burden posed by cardiac arrest and the increased emphasis of improving the quality of ECC, there is a necessity to reexamine cardiac arrest management practices and performance. At an organisational level there is a responsibility to invest in quality improvement processes that should be a continuous cycle of (1) measurement, a systematic evaluation of resuscitation care and outcome, (2) benchmarking, where the data is systematically reviewed both internally and externally to compare performance, and (3) the strategic impetus to address gaps and deficiencies that have been identified (Travers, et al., 2010). The cardiac quality improvement processes should include both in-hospital and out-of-hospital cardiac arrest.

During the management of an out-of-hospital cardiac arrest paramedics may perform chest compressions either positioned from-the-side (FTS) of the patient, the standard position, or positioned at the head performing compressions over-the-head (OTH). The OTH technique was introduced in the 1990's as a solution to performing CPR in a confined space such as the aisle of a train or aeroplane (Perkins, et al., 2004). The OTH position also enables efficient use of a manual bag mask ventilation device by a single rescuer and allows one rescuer to perform CPR whilst another performs additional tasks such as applying defibrillation patches or gaining intravenous access (Bollig, et al., 2007). Since the introduction of the OTH technique there have been numerous modifications to the recommendations and consensus statements pertaining to resuscitation. In light of the recent emphasis on chest compression quality and consistent with the quality improvement process it is prudent to reconsider the utility of the OTH technique as a means of delivering chest compressions.

The aim of this review is to examine the literature to determine whether there is a difference in the quality of cardiopulmonary resuscitation (CPR) when chest compressions are performed FTS or OTH.

Methods

PICO question

This review sought to identify evidence to address the PICO (Patient/population, Intervention, Comparator, Outcome) question: In healthcare providers performing CPR (P), does the OTH position for performing chest compressions (I), when compared to the standard FTS position (C), result in a significant difference in the quality of CPR (O)?

Search strategy

The Electronic databases Cochrane, Medline, CINAHL, Scopus and Biomedical Reference collection (OVID and EBSCO) were searched using the key terms “over-the-head” OR “over-the-head” AND “CPR’ OR “cardiopulmonary resuscitation”. Articles describing over-the-head CPR were eligible for inclusion. Limits included language (English), full text journal articles and date of publication (2000 to 2013). The date range was selected so that the data collection period was not substantially influenced by protocol changes due to updates to the Resuscitation Guidelines, that are published every five 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 is summarised in Figure 3.

Evidence appraisal

After reviewing the studies they were classified by the level of evidence (LOE) based on the International Liaison Committee on Resuscitation (ILCOR) levels of evidence for therapeutic interventions (Table 2). Quality was also rated as either poor, fair or good, based on agreed definitions (Sayre, O'Connor, et al., 2010)

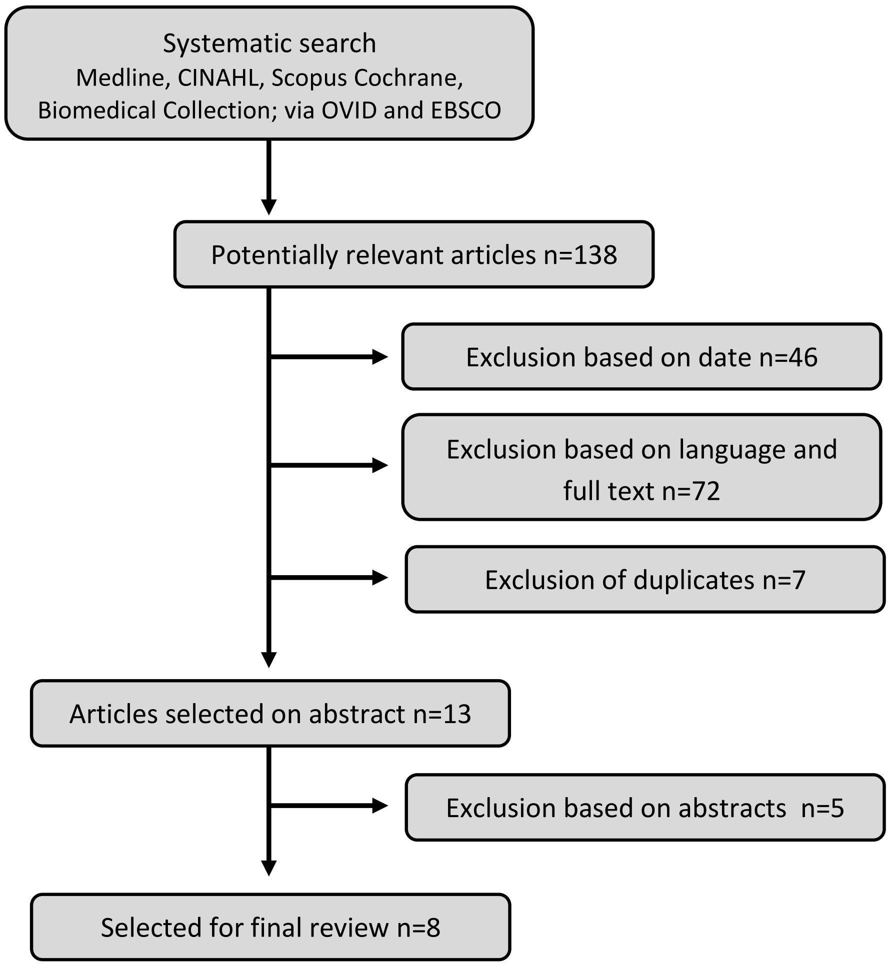


Figure 3. Search and selection process

Studies where CPR was performed on manikins automatically received the classification of LOE 5 irrespective of the study design. Manikin studies of higher quality of evidence were classified as good. Lastly, studies were classified according to whether they supported, were neutral or opposed the PICO statement.

Table 2. ILCOR levels of evidence for therapeutic interventions

LOE 1:	Randomised control trials (or meta-analysis of RCT's)
LOE 2:	Studies using concurrent controls without true randomisation (e.g. "pseudo-randomised" or meta-analysis of such studies)
LOE 3:	Studies using retrospective controls
LOE 4:	Studies without a control group (e.g. case series)
LOE 5:	Studies not directly related to the specific patient/population (e.g. different patient/population, animal models, mechanical models etc.)

ILCOR= International Liaison Committee on resuscitation LOE = Level of Evidence

Results

The search identified a total of 138 potentially relevant papers. After exclusion based on date, English language, full text and duplicates a total of 13 articles were deemed relevant. After reviewing the abstracts a further five articles were excluded as they did not directly compare OTH and FTS positions for performing chest compressions, leaving eight articles for full review.

There were no randomised controlled trials, or meta-analyses of such, that investigated OTH CPR involving human cardiac arrest patients (LOE 1). Likewise no LOE 2, LOE 3 or LOE 4 studies were identified. All of the eight studies selected for review were LOE 5 studies conducted with a simulated cardiac arrest using patient simulators or manikins. By definition LOE 5 studies are studies not directly related to the specific patient/population, in this case human cardiac arrest victims. The level of evidence, quality and support of PICO question for the papers are summarised in Table 3.

Table 3. Summary of level and quality of evidence supporting or opposing the PICO question

Level of evidence	LOE 1	LOE 2	LOE 3	LOE 4	LOE 5
Evidence supporting the PICO question (supporting the use of OTH)					
Good					Maisch et al (2011) Handley & Handley (2004) Perkins et al (2004) Hupfl et al (2005) Chi et al (2009)
Fair					Bollig et al (2007) Brucke et al (2007)
Poor					
Evidence neutral to the PICO question					
Good					
Fair					
Poor					
Evidence opposing the PICO question (opposing the use of OTH)					
Good					Maisch et al (2010)[a] Handley & Handley (2004)[a]
Fair					
Poor					

[a] comparison of single-rescuer OTH to two-rescuer CPR

Table 4. Summary of studies describing over-the-head CPR

Authors	Health provider	Guidelines	Study design/protocol	Duration of CPR	Key findings
Maisch, S., Gamon, E., Llisch, A., Goetz, A. & Schmidt, G. (2011)	n=102 69 paramedics, 33 EMT's	2005 30:2	Randomised crossover, audio prompt for rate, Each participant attempted 5 different methods, single rescuer: FTS, OTH, alternating, two rescuer: ventilating, chest compressions. Ventilations by BVM	2 min	OTH superior to FTS CPR for single rescuer using BVM. Hands-off time OTH=FTS, chest compressions in 2 minutes significantly greater with OTH. Number of ventilations OTH=FTS. Significantly more correct ventilations in OTH
Maisch, S., Issleib, M., Kuhls, B., Mueller, J., Horlacher, A., Goets, A. & Schmidt, G. (2010)	n=106 106 medical students (year 3-5)	2005 30:2	Randomised crossover, three protocols: single rescuer OTH, the ventilator at the head whilst another rescuer performed compressions FTS, and FTS whilst another rescuer ventilated (BVM) from the head,	2 min	For two rescuers, standard CPR (chest compressions FTS other rescuer ventilates at head) provides better quality of CPR compared to over-the-head CPR by a single rescuer
Chi, C., Tsou, J. & Su, F. (2009)	n=21 15 EMT firefighters, 6 nurses	2005 30:2	Randomised crossover: Randomised to either OTH or FTS and crossover	2 min	No differences in kinematics, compression forces, depths and frequencies between the two positions
Bollig, G., Steen, P. & Wik, L. (2007)	n=8 Paramedic students	2000 15:2	Randomised crossover, pair randomised to rescuer 1 or 2 and then randomised to FTS or OTH, Ventilations by BVM	Variable from193 to 265 s	No difference in: ventilation parameters, compression rate, duty cycle, mean depth or hands-off time
Brucke, M., Helm, M., Schwartz, A. & Lampl, L. (2007)	n=20 10 HEMS teams of Drs and paramedics	2005 30:2	Pilot study assessing composite OTH and FTS CPR during a simulated resuscitation event. No randomisation nor control, results compared to guidelines	10 min	Concluded proven feasibility of the OTH and FTS composite protocol when CPR quality metrics are compared to the guidelines
Hupfl, M., Duma, A., Uray, T., Maier, C., Fiegl, N., Bogner, N. & Nagele, (2005)	n=67 EMT students	2000 15:2	Randomised crossover: Randomised to either OTH or FTS and crossover	2 min	OTH resulted in superior ventilation and no significant difference in all chest compression quality parameters
Handley, A. & Handley, J. (2004)	n=19 Airline Crew instructors in BLS	2000 15:2	Randomised crossover – four protocols: 1 person from-the-side, 2 person from-the side, one person over-the-head, 2 person straddled. 3 minute rest between positions. Ventilations by pocket mask	Four cycles ~ 60 s	Two Rescuer CPR (STD and Straddle positions): No significant differences in all parameters measured Single Rescuer CPR: No difference in: hands-off time, compression rate, number of compressions in 1 minute. Significant difference in: depth (OTH shallower), duty cycle (OTH greater), hand placement errors (OTH more errors) Two rescuer CPR was superior to one rescuer CPR
Perkins, G., Stephenson, B., Smith, C. & Gao, F. (2004)	n=20 BLS instructors	2000 15:2	Randomised crossover: Randomised to either OTH or FTS and crossover 7 days later	3 min	No difference in: ventilation, compression rate, duty cycle, mean depth or hands-off time. Hand position errors were less in the OTH position

OTH: over-the-head, FTS: from-the-side, BVM: bag valve mask manual ventilator, HEMS: Helicopter Emergency Medical Service, BLS: Basic Life Support, EMT: Emergency Medical Technician, 30:2: 30 compressions to 2 ventilations, 15:2: 15 compressions to 2 ventilations

The key findings, study protocol, type and number of health provider, guideline year and the duration of chest compressions for the eight studies reviewed are summarised in Table 4.

Chest compression rate and number

Chest compression rate and the number of compressions per minute have been identified as a quality marker for CPR (Kramer-Johansen, et al., 2007). Of the studies reviewed six directly compared compression rate between OTH and FTS positions. All six studies indicated that there was no difference in the rate of compressions between FTS or OTH positions, Table 5 (Bollig, et al., 2007; Chi, Tsou, & Su, 2009; Handley & Handley, 2004; Maisch, Gamon, Ilisch, Goetz, & Schmidt, 2011; Maisch et al., 2010; Perkins, et al., 2004).

Table 5. Chest compressions performed OTH and FTS by a single rescuer

	Compression Rate			Compressions per minute			Depth of compression		
	OTH	FTS	*p* value	OTH	FTS	*p*	OTH	FTS	*p* value
Bollig et al (2007)	101	103	0.57	52	50	0.672	42	42	0.72
Handley & Handley (2004)	82.1	81.7	0.78	44.6	45.1	0.526	34.8	37.6	0.02*
Hupfl et al (2005)				49.5	49.5	0.98			
Maisch et al (2011)	106	106	-	77.5	76	<0.05*	44	44	>0.05
Chi et al (2009)	111	110	0.64	113	110	0.18	47.1	47.5	0.65
Perkins et al (2004)	107.2	107.4	0.83	50	47	0.012*	38.1	38.5	0.79
Maisch et al (2010)	102	103	0.70	71	83.5	<0.001*	45	42	0.02*

OTH: Over-the-head, FTS: From-the-side *P < 0.05 significant

Seven studies compared the number of compressions delivered in one minute for both the FTS and OTH positions. Four of the studies reported no significant difference in the number of compressions delivered (Bollig, et al., 2007; Chi, et al., 2009; Handley & Handley, 2004; Hupfl et al., 2005). Of the three studies that showed a significant difference in the number of compressions performed in one minute, two report a higher number of chest compressions associated with the OTH position (Handley & Handley, 2004; Maisch, et al., 2011) and one identified more compressions being performed FTS (Maisch, et al., 2010). The study by Maisch et al (2011) compared single-rescuer CPR with manual bag valve mask ventilation with the rescuer positioned FTS and OTH, reporting that there were significantly more chest compressions in a 2 minute period when CPR was performed OTH compared to FTS (OTH: 155; FTS:152, $p<0.05$). This study also compared single-rescuer OTH to two-rescuer FTS CPR where the rescuer performing ventilation was positioned at the head and the rescuer performing chest compressions was positioned FTS. In this setting no difference in compression rate was observed however a significant difference in the number of compressions performed in two minutes between single-rescuer OTH and two-rescuer FTS CPR was identified (two-rescuer FTS: 180 min^{-1}; Single-rescuer OTH: 155 min^{-1}, $p<0.05$). Handley and Handley (2004) also report that two-rescuer FTS CPR has a significantly greater number of compressions performed in one minute compared to single-rescuer OTH CPR (STD: 57.5 min^{-1}, OTH:44.6 min^{-1}, $p=0.0001$) although there was no significant difference in compression rate.

One study did not directly compare OTH to FTS; Brucke et al (2007) conducted a two-rescuer CPR study in which the rescuer positioned at the head performed CPR OTH for two minutes followed by the second rescuer performing CPR positioned FTS. This alternating sequence continued for the duration of the study with the aim of demonstrating that an OTH/FTS composite technique achieved a CPR performance that meets the standards stipulated in the 2010 Resuscitation Guidelines. This study demonstrated higher compression rates (120.1 min^{-1}) and compressions delivered per minute with the composite OTH-FTS CPR protocol than reported in the Maisch and Handley studies (Brucke, Helm, Schwartz, & Lampl, 2007; Handley & Handley, 2004; Maisch, et al., 2011).

Chest compression depth

Chest compression depth has been shown to be associated with cardiac arrest survival (Edelson et al., 2006; Kramer-Johansen, et al., 2007; Stiell et al., 2012; Vadeboncoeur et al., 2014) with current adult resuscitation guidelines recommending a chest compression depth of greater than 50mm (Travers, et al., 2010). Seven of the reviewed articles directly compared compression depth when compressions are performed FTS and OTH; of which five studies reported no difference in compression depth between the two positions (Bollig, et al., 2007; Chi, et al., 2009; Hupfl, et al., 2005; Maisch, et al., 2011; Perkins, et al., 2004), Table 5.

In Table 5 there are no compression depth values included from the study by Hupfl et al (2005). They do not directly report mean compression depth however report no significant difference in the number of compressions that were too shallow (less than 38mm) between OTH and FTS CPR. Similarly Perkins et al (2004) found no significant difference in compression depth between the two positions (OTH: 38.1mm, FTS: 38.5mm, p=0.789) and reported that the depth of compression declined over time for both positions.

Three of the studies reviewed reported a significant difference in observed compression depth between positions. One single-rescuer study by Handley and Handley found a significant difference in the depth of compressions between the OTH and FTS CPR positions (OTH: 34.8mm, FTS: 37.6mm, p=0.0149) with the OTH position demonstrating shallower compression depth (Handley & Handley, 2004). The other two studies compared two-rescuer FTS CPR to OTH single-rescuer CPR. The 2010 study by Maisch et al identified that the depth of chest compression was significantly deeper when one rescuer performs CPR OTH compared to two-rescuers performing FTS CPR (FTS: 42mm, OTH: 45mm, p=0.02). The percentage of compressions that were less than 40mm was significantly higher in the two-rescuer FTS CPR (FTS: 14.6%, OTH 2.6%, p=0.004) whereas the percentage of compressions between a depth of 40 and 50mm was significantly greater in the OTH CPR (FTS: 65.3%, OTH 66.2%, p=0.04) (Maisch, et al., 2010). A subsequent study by Maisch et al (2011) similarly reported significant difference in chest compression depth between single-rescuer OTH CPR and two-rescuer FTS CPR (OTH: 44mm, FTS: 43mm, $p<0.05$) (Maisch, et al., 2011). Brucke et al (2007) reported a mean compression depth of 46.6mm for the composite OTH-FTS two-rescuer CPR protocol with 11.8% of compressions performed at a depth of less than 40mm and 59.4% of compressions falling within the depth of 40mm and 50mm (Brucke, et al., 2007).

Leaning

Leaning occurs when the person performing the chest compression does not allow the chest wall to completely recoil on the up-stroke of the chest compression due to exerting a residual pressure on the chest at the end of the compression. Of the studies reviewed only four reported incidence of leaning. Only two of these studies directly compared single-rescuer OTH and FTS CPR, both found no significant difference in the incidence of leaning between positions (Bollig, et al., 2007; Maisch, et al., 2011). The reported incidence of leaning was low, one study reported a zero incidence of leaning (Bollig, et al., 2007), the other had an observed incidence of leaning of 3.2% and 1.3% for OTH and FTS positions respectively (Maisch, et al., 2011).

One study compared the incidence of leaning between two-rescuer FTS CPR and single-rescuer OTH CPR and reported that the two-rescuer FTS CPR had a significantly higher percentage of compressions exhibiting leaning than single-rescuer OTH CPR (FTS: 0.6%, OTH: 0.3%, $p<0.001$), similarly showing a low incidence of leaning (Maisch, et al., 2010). The composite OTH-FTS two-rescuer CPR study by Brucke et al (2007) reported an incidence of leaning of 7.3%, an observed rate which is higher than the other studies (Brucke, et al., 2007).

Chest compression duty cycle

The duty cycle is reported as a percentage and represents the time spent compressing the chest as a proportion of the time between the start of one cycle of compression and the start of the next and thus reflects the active downward pressure on the chest. Three of the studies reviewed investigated the influence of position on duty cycle with two of the three reporting no significant difference in duty cycle between OTH and FTS positions (Bollig et al: OTH: 43%, FTS: 42%, p=0.54, Perkins et al: OTH: 44%, FTS: 44.1%, p=0.917) (Bollig, et al., 2007; Perkins, et al., 2004). The third study reported a significant difference in duty cycle between positions with OTH having a higher duty cycle compared to chest compressions performed in the FTS position (OTH:44.5%, FTS:40.8%, p=0.0045).

Chest compression fraction (including no-flow time or hands-off time)

Chest compression fraction (CCF) is defined as the proportion of the resuscitation period that chest compressions are being performed and has been shown to be an independent predictor of survival (Christenson et al., 2009). Only one study directly measured CCF however five additional studies reported hands-off time or time to perform two ventilations per cycle which allows calculation of CCF from the total time per cycle. Four studies directly compared CCF or hands-off time for single-rescuer OTH and FTS CPR and reported no significant difference in CCF/hands-off time between positions (Bollig, et al., 2007; Handley & Handley, 2004; Hupfl, et al., 2005; Maisch, et al., 2011)

Table 6. Chest compression fraction associated with OTH and FTS CPR

	OTH	FTS	*p*
Bollig et al (2007)	50%	48%	0.92
CCF reported as hands-off time			
Handley & Handley (2004)**	10.3s	10.3s	1.00
Hupfl et al (2005)**	5.5s	6.0s	0.07
Maisch et al (2011)#	74.2%	74.2%	>0.05
Two Rescuer FTS compared to single rescuer OTH CPR			
Handley & Handley (2004)**	10.3s	6.2s	<0.01*
Maisch et al (2010)#	68.3%	79.6%	<0.01*

= CCF derived from hands-off time, ** = Time take to deliver two breaths
*$p < 0.05$ significant, OTH = Over-the-head, FTS = From-the-side

Two studies compared single-rescuer OTH to two-rescuer FTS CPR and both found a significant difference in the hands-off time, and therefore CCF, with two-rescuer FTS CPR being superior to single-rescuer OTH CPR, Table 6 (Handley & Handley, 2004; Maisch, et al., 2010). Brucke et al (2007) found that the chest compression fraction associated with the composite OTH-FTS two-rescuer CPR was 83.9% (no-flow fraction of 16.1%) which is a superior CCF compared to the Maisch et al (2010) and Handley and Handley (2004) studies.

Correct hand positions

Achieving the correct hand position for chest compressions in the adult is described the 2010 Resuscitation Guidelines as placing “the heel of one hand on the centre of the chest, which is the lower part of the sternum, with the heel of the other hand on top of the first so that the hands are overlapped and parallel” (Berg et al., 2010, p. S690). A total of six studies reported incidence of hand position errors. Three of the six studies found no difference in hand placement errors between positions (Bollig, et al., 2007; Hupfl, et al., 2005; Maisch, et al., 2011). One study reported more frequent hand errors associated with the FTS CPR group (OTH 76 errors, FTS: 300 errors, p<0.0001) (Perkins, et al., 2004). Conversely another study found that the OTH position resulted in significantly more hand position errors during chest compressions compared to the FTS position, OTH: 30.4%, FTS:7.7%, $p=0.0025$ (Handley & Handley, 2004). The majority of the hand position errors for either FTS or OTH compressions were due to the hands being positioned too low, over the epigastric area. One study reported hand position errors compared between single-rescuer OTH and two-rescuer FTS CPR and observed significantly more hand position errors associated with OTH single-rescuer CPR (FTS: 0%, OTH: 18%, $p<0.001$) (Maisch, et al., 2010).

Ventilations

The 2010 Resuscitation Guidelines recommend a compression ventilation ratio of 30:2 with each ventilation being delivered over one second and having a volume of 500–600mL (6 to 7mL/kg) to achieve a ventilation rate of 8–10 per minute (Berg et al., 2010). Of the studies reviewed five report ventilation parameters; four out of the five show no difference in the number of ventilations delivered as a part of the resuscitative event when compressions are performed OTH or FTS (Bollig, et al., 2007; Hupfl, et al., 2005; Maisch, et al., 2011; Perkins, et al., 2004). One study observed less ventilations delivered (OTH: 8, FTS: 10, $p<0.001$) with single-rescuer OTH CPR compared to two-rescuer FTS CPR (Maisch, et al., 2010). All studies reported ventilation rates in the range of 8–10 per minute, consistent with Guideline recommendations.

Three of the five studies showed no significant difference in the ventilation volume delivered between OTH and FTS (Bollig, et al., 2007; Maisch, et al., 2010; Perkins, et al., 2004). Two studies identified greater ventilation volumes were achieved when CPR was performed in the OTH position (Hupfl, et al., 2005; Maisch, et al., 2011). Maisch et al (2011) reported the ventilation tidal volume in mL: OTH: 415mL, FTS: 345mL ($p<0.05$), whereas Hupfl et al (2005) reported the percentage of ventilations with the correct tidal volume (OTH: 43.9%, FTS: 35.8%, $p<0.001$).

The time taken to deliver two ventilations was reported in three studies. One study showed no significant difference in time to deliver two ventilations (Hupfl, et al., 2005; Maisch, et al., 2011). One study showed that the time taken to deliver two inflations was significantly shorter for the OTH position (OTH: 6.8s, FTS: 7.3s, $p<0.05$)(Maisch, et al., 2011), conversely the other study reported time taken to deliver two inflations was also significantly longer for the OTH technique (OTH: 9.5, STD: 4.8s, $p<0.001$)(Maisch, et al., 2010). The composite OTH and FTS CPR protocol study by Brucke et al (2007) showed an average ventilation rate of 9 per minute with 68.9% of the ventilations having a tidal volume greater than 600mL.

Chest compression kinematics

One study evaluated the effect of OTH CPR on the kinematics and force associated with delivery of chest compressions and compared these to those associated with FTS CPR (Chi, et al., 2009). No significant differences in the ranges of motion of the head, shoulder, elbow, wrist, lower trunk, hip, knee and ankle were detected between the two positions. Likewise there was no significant difference in compression forces between OTH and FTS CPR (OTH: 386.64 ± 47.32N, FTS: 397.35 ± 41.89N, $p>0.05$) (Chi, et al., 2009).

Rescuer preference of CPR position

Two studies investigated the rescuer preference for position of performing chest compressions. Both studies report a higher preference for OTH than FTS as a position for performing chest compressions (Maisch, et al., 2011; Maisch, et al., 2010). Maisch et al (2011) reported the preferred CPR technique of 102 emergency medical technicians performing single-rescuer CPR with BVM was OTH 86.3%, FTS 7.8% and alternating 2.9%, no preference 2.9%. Similarly in a study of 106 medical students which compared two-rescuer FTS CPR to single- rescuer OTH CPR, 50% preferred OTH CPR, 37.7% preferred two-rescuer FTS CPR and 12.3% had no preference (Maisch et al, 2010).

Discussion

The principle finding of this review is that in simulated conditions CPR performed OTH results in CPR quality similar to that observed with CPR performed FTS. The evidence suggests that it would be reasonable to use OTH CPR as an alternative to single-rescuer FTS CPR, particularly if ventilating with a BVM. Secondly, it appears that in simulation, two-rescuer CPR may provide superior CPR quality to single-rescuer OTH CPR. There is a dearth of literature describing OTH CPR with no studies describing this practice during human studies. Of the few manikin studies identified for review there is obvious heterogeneity in methods, participant skill and experience, quality parameters reported and the clinical protocol used.

One inconsistency in design is the degree of training associated with the studies. Three studies did not incorporate training into the study design (Brucke, et al., 2007; Chi, et al., 2009; Hupfl, et al., 2005) whereas the other five studies did (Bollig, et al., 2007; Handley & Handley, 2004; Maisch, et al., 2011; Maisch, et al., 2010; Perkins, et al., 2004). Handley and Handley (2004) provided 15 minutes instruction of OTH and straddle CPR and gave opportunity for the participants to practise FTS CPR. Perkins et al (2004) provided training in both OTH and FTS CPR for an unspecified time one hour prior to commencement of the study. Maisch et al (2010) provided 90 minutes of training and 15 minutes of practice opportunity. Both Bollig et al (2007) and Maisch et al (2011) provided 15 minutes of tuition and 15 minutes of practice for single-rescuer OTH CPR only. Previous manikin studies have highlighted that the quality of CPR performance by both lay people and health professionals deteriorates significantly within months of training (Wik, et al., 2005). Training immediately prior to the study may influence performance as multiple studies have shown poor retention of CPR psychomotor skill performance at 3 months post-training (Madden, 2006; Niles, Sutton, et al., 2009).

Training may also have influenced the reported incidence of leaning. The incidence of leaning, or incomplete hand release, was not found to be significantly different between single-rescuer FTS or OTH CPR. Only four studies reported leaning, one study reporting a zero incidence of leaning and another reporting 3.2% and 1.3% leaning with OTH and FTS single-rescuer CPR respectively (Bollig, et al., 2007; Maisch, et al., 2011). The incidence of leaning observed is low; human studies have reported an incidence of leaning ranging from 12–50% of all compressions delivered (Fried et al., 2011; Niles et al., 2011). The reported low incidence of leaning in these studies may be due to the participants undergoing CPR training prior to participation, the short duration of performing chest compressions and the relatively controlled environment associated with a simulated setting.

All studies conclude that there was no significant difference in compression rate when comparing the two positions for performing CPR and between single and two-rescuer CPR protocols. However there were conflicting results with respect to the comparison of the number of compressions delivered per minute. The number of compressions delivered per minute is often less than the compression rates due to pauses in compressions associated with other interventions such as defibrillation and ventilation. This explains why the study by Chi et al (2009), in which only chest compressions were performed, reported 110 compressions delivered per minute, which is much higher than the other studies(Chi, et al., 2009).

Two studies reported greater numbers of compressions performed per minute when compressions are delivered OTH (Maisch, et al., 2011; Perkins, et al., 2004). The difference in compressions delivered was between a total of two and three. It is not clear if such a small difference would have any clinical relevance. These findings may be influenced by factors inherent to the studies that may have impacted the number of compressions performed in a minute. Such factors include different compression to ventilation ratios (15:2 and 30:2), the use of an audio feedback rate prompt or metronome and the type of adjunct used to deliver the ventilations.

One study reported less compressions delivered per minute when single-rescuer OTH was compared to two-rescuer FTS CPR (Maisch, et al., 2010). The difference in this setting was approximately 13 compressions per minute which is more likely to be clinical relevant. The difference may be explained by the additional time required for ventilation as it may take longer to position the mask and ventilate when a single rescuer is performing CPR.

Three studies used an audio prompt device to provide guidance on the rate of compressions (Hupfl, et al., 2005; Maisch, et al., 2011; Maisch, et al., 2010) whereas in the other five studies participants had no guidance on the correct rate to perform the compressions. The use of a metronome to guide compression rate has been previously reported to correct compression rate to align with recommended guidelines and resulted in significantly shorter no-flow times and time taken to ventilate (Jantti, Silfvast, Turpeinen, Kiviniemi, & Uusaro, 2009).

The time taken to ventilate took longer when CPR was performed by one rescuer compared to two (Handley & Handley, 2004; Maisch, et al., 2010). There were different techniques or devices used to achieve ventilation. The review identified four studies that used a bag valve mask to ventilate for both positions (Bollig, et al., 2007; Brucke, et al., 2007; Maisch, et al., 2011; Maisch, et al., 2010) and two studies that used a pocket mask (Handley & Handley, 2004; Perkins, et al., 2004); of which one used the researcher to provide the ventilations (Handley & Handley, 2004) , one study utilised a bag valve mask to ventilate during OTH CPR and mouth to mouth for FTS CPR (Hupfl, et al., 2005) and one study did not include ventilation, focusing entirely on chest compressions only (Chi, et al., 2009). The different ventilation modalities may be a confounder.

The study duration in which the participants performed CPR varied, with two minutes being the most common time period. The standard duration of a cycle of CPR is two minutes with Guidelines suggesting that if multiple rescuers are available the person performing the chest compressions should change every two minutes (Travers, et al., 2010). The short duration may also reflect the intended use of OTH CPR during the initial phase of the resuscitation in which one rescuer performed OTH CPR whilst either additional rescuers were recruited or the second rescuer performed other tasks such as using the defibrillator, establishing intravenous access and preparing medications for later use (Maisch, et al., 2011).

Limiting the duration of chest compression performance does not facilitate the investigation of the effect that rescuer fatigue may have on the quality of chest compressions performed FTS or OTH. The effect that fatigue has on CPR quality is variably described with multiple studies showing rescuer fatigue results in a deterioration of CPR quality over time, particularly chest compression depth and rate (Foo, Chang, Lin, & Guo, 2010; Perkins, et al., 2004; Vaillancourt, Midzic, Taljaard, & Chisamore, 2011). Conversely other studies report no deterioration in CPR quality over time (Bjorshol, Sunde, Myklebust, Assmus, & Soreide, 2011; Haque et al., 2008). One of the studies reviewed had a duration of CPR of 10 minutes (Brucke, et al., 2007). This study used a composite rescuer position protocol where the physician was positioned at the head and the paramedic was positioned at the side of the manikin for the duration of the simulated resuscitation. The pair alternated who performed the chest compressions every two minutes for a total of ten minutes. The physician performed OTH compressions and the paramedic performed FTS CPR. CPR quality was reported to show compliance with the 2005 Guidelines with the exception of the incidence of leaning.

Resuscitation Guidelines describe the corrected hand position as “the heel of one hand on the centre of the chest which is the lower part of the sternum with the heel of the other hand on top of the first so that the hands are overlapped and parallel” (Berg, et al., 2010, p. S690). Several studies used a hand position for OTH CPR in which the heel of the hand was placed perpendicular to the sternum (Bollig, et al., 2007; Handley & Handley, 2004; Hupfl, et al., 2005; Maisch, et al., 2011; Maisch, et al., 2010; Perkins, et al., 2004). There were no studies identified that report if this modified hand position is associated with increased risk of skeletal trauma for the victim. Most studies reviewed found no difference in hand position errors between positions. The study by Handley and Handley (2004) found more hand placement errors associated with the OTH position. One explanation offered for this was that the airline BLS instructors had no experience of the OTH technique prior to the study. Conversely Perkins et al (2004) reported less hand placement errors associated with the OTH position and these participants also had no previous knowledge or training in the OTH technique. One difference between these two studies is that the participants in the Perkins study had some, albeit minimal, clinical experience of CPR whereas the Handley study participants did not. The difference in experience may have influenced performance.

The degree of previous experience of CPR between the studies is heterogeneous. Of the eight studies reviewed, four used participants who were health students and two used BLS instructors. In only three studies did the participants have reasonable experience in clinical resuscitation (Brucke, et al., 2007; Chi, et al., 2009; Maisch, et al., 2011). Two studies had low levels of clinical experience (Maisch, et al., 2010; Perkins, et al., 2004) and three studies had no clinical experience (Bollig, et al., 2007; Handley & Handley, 2004; Hupfl, et al., 2005). The diversity of experience may explain the difference, for example, in the chest compression fraction between paramedics (74%) and paramedic students (50%) (Bollig, et al., 2007; Maisch, et al., 2011).

The chest compression fraction (CCF) represents the proportion of time that chest compressions are being performed and has been shown to be an independent predictor of survival for out-of-hospital ventricular fibrillation cardiac arrests (Christenson, et al., 2009). Survival increases as CCF increases with a peak survival reported with a CCF between 60 and 80%. Of the studies reviewed, four studies directly compared single-rescuer OTH to single-rescuer FTS and all reported no significant differences in CCF or time without chest compressions (Bollig, et al., 2007; Handley & Handley, 2004; Hupfl, et al., 2005; Maisch, et al., 2011). Two studies compared two-rescuer FTS to single-rescuer OTH. One observed greater times taken to ventilate and the other reported lower CCF values associated with single-rescuer OTH CPR (Handley & Handley, 2004; Maisch, et al., 2010). One explanation could be the additional time it takes for a single rescuer to pick up the ventilation bag, ventilate and then re-locate the correct hand position before recommencing chest compressions. Only one study directly reported CCF, others reported delays in chest compressions associated with the time to ventilate and hands-off time. Having standard reporting of CPR quality metrics would facilitate better direct comparison of study outcomes.

Conclusion

The heterogeneity of design, metrics reported, short duration of CPR performed and few studies identified for review, make it difficult to conclusively determine the utility of using OTH CPR. It is reasonable to suggest that, in manikin studies at least, chest compressions performed OTH may result in a similar quality of CPR when compared to chest compressions performed FTS over a short time period. There are conflicting results pertaining to the use of single-rescuer OTH CPR compared to two-rescuer FTS CPR. Further manikin studies based on the 2010 Resuscitation Guidelines and that assesses OTH CPR for longer periods, to investigate the influence that fatigue may have on CPR quality, are needed. As no human randomised controlled trials have been conducted it is not possible to comment on the translation of these findings to clinical practice. Further studies that use standardised reporting of CPR quality parameters, in which CPR is performed on human cardiac arrest victims, would be needed to conclusively recommend the use of OTH CPR during clinical resuscitation.

CHAPTER 3

COMPARISON OF EXTERNAL CHEST COMPRESSIONS MEASURED USING LAERDAL SKILL REPORTER AND Q-CPR: A MANIKIN STUDY.

Overview

There has been an increased emphasis on the quality of chest compressions as a part of the cardiopulmonary resuscitation (CPR) care bundle over recent times. During CPR training chest compression quality parameters can be measured directly from sensors within a manikin or from independent devices that use accelerometer based technology. The aim of this study was to compare external chest compression data from the manikin-based Laerdal Skill Reporter (LSR) and the puck-based Q-CPR® technology during CPR on a Resusci Anne® simulator manikin.

Methods: Paramedics (n=15) each performed two sessions of two minutes of chest compressions, with a two minute rest period in between sessions. Both over-the-head (OTH) and from-the-side positions (FTS) were used. The quality of chest compressions were concurrently measured using both Q-CPR® and the Laerdal Skill Reporter systems with audio-visual feedback disabled.

Results: There was no significant difference in the measurement of the number of chest compressions performed in two minutes, the compression rate, total number of compressions of adequate depth or the number of compressions exhibiting leaning between the LSR and Q-CPR® devices. There was a significant difference in compression depth ($p<0.0001$) and duty cycle (<0.0001).

Conclusion: There was no significant difference in the majority of chest compression quality metrics measured between the LSR and the Q-CPR® devices. However, there were significant differences in the measurement of duty cycle and also the depth of compressions between the two devices. These differences were observed to increase with an increasing incidence of leaning.

Introduction

Sudden out-of-hospital cardiac arrest (OHCA) is a significant health burden, with an average incidence of 83/100,000 per year (Nolan et al., 2010). Epidemiological studies of OHCA show variability in both incidence and survival rates. The incidence in the USA and Europe have been reported as 55/100,000 per year (range 17-128/100,000) and 81/100,000 per year (range 19 to 173 per 100,000) respectively, with survival to discharge rates ranging from 1.8 to 21.8% (Grasner & Bossaert, 2013). Quality of chest compressions have been identified as influencing survival rates from cardiac arrest both in-hospital and out-of-hospital (Abella, et al., 2005; Christenson, et al., 2009; Nolan, et al., 2010; Wik, et al., 2005).

There has been an increased emphasis on the quality of chest compressions and a de-emphasis on ventilation as a part of the cardiopulmonary resuscitation (CPR) care bundle over recent times (Travers, et al., 2010). Manikin-based cardiopulmonary chest compression quality parameters can be measured directly from sensors within a manikin. These quality measurements can then be utilised to provide feedback during CPR training. The ability to measure CPR quality and provide feedback has been shown to improve both performance and retention of CPR skills (Yeung et al., 2009). An example of a system that utilises this technology is the Laerdal skill reporter (LSR). The LSR uses a linear chest compression sensor based within the Resusci Anne® manikin. In this setting a vertical chest wall motion induces movement of an internal pivot that acts upon a potentiometer to produce an analogue signal.

An alternative method for measuring CPR quality parameters and providing feedback is through the use of a puck-based system. Unlike the manikin-based technology that takes measurements from sensors located within a manikin's chest a puck-based system utilises an external device, a puck, that is placed on the outside of a manikin's chest through which measurements are made externally. In addition to being able to provide feedback in a simulated environment due to its external location a puck can also be utilised in a clinical setting. The Q-CPR® is an example of puck-based technology. The Q-CPR® is incorporated into the MRx defibrillator (Philips Medical Systems, Andover, USA), using an accelerometer and force detector to measure chest compression quality, providing real time automated audio and visual feedback during CPR. The use of Q-CPR® has been shown to improve CPR quality during training and in out-of-hospital cardiac arrest (Kramer-Johansen et al., 2006; Vivier, 2010). Q-CPR® has reportedly been validated for compression depth measurement with a mean error of measurement of 1.6mm when chest compressions are performed on a manikin positioned on a flat, firm floor (Aase & Myklebust, 2002). It should be noted, however, that this study is limited by its sample size being only one external chest compression event of three minutes duration.

In the out-of-hospital environment the health care professional providing care during cardiac arrest is often a paramedic. With respect to external chest compression the paramedic may elect to perform chest compressions in the traditional position of from-the-side, or alternatively positioned over-the-head of the cardiac arrest victim. The over-the-head chest compression technique was introduced in the 1990's as a solution to performing CPR in confined spaces and for a single rescuer ventilating with a manual bag ventilator (Bollig, et al., 2007).

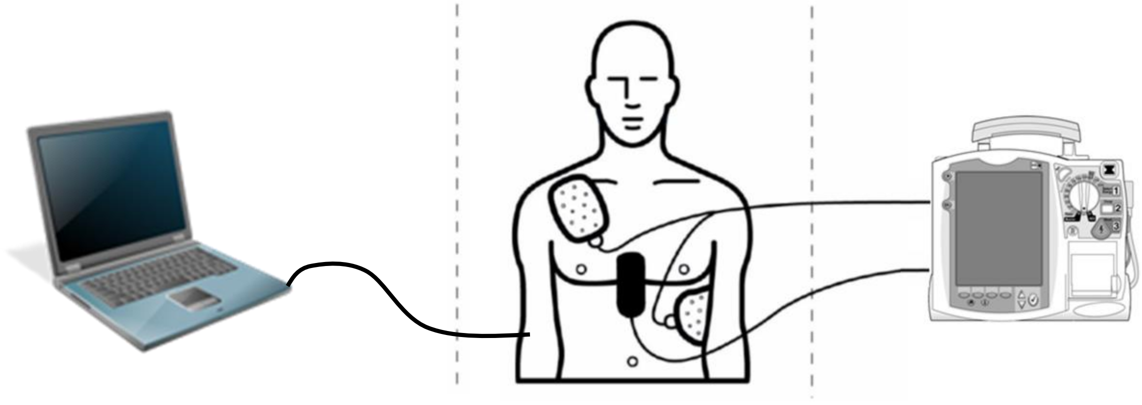
This study seeks to compare external chest compression data from the manikin-based LSR technology to the puck-based Q-CPR® technology during CPR on a Resusci Anne®Simulator manikin. This will inform the suitability of using Q-CPR® as an alternative tool for assessing paramedic chest compression performance during CPR training.

Methods

Study design

External chest compressions were performed on a Resusci Anne®Simulator manikin and compression variables were simultaneously measured by the LSR and the Q-CPR®. Data was recorded using Laerdal PC Skill Reporting System software, version 2.4.1 (Laerdal Medical Corporation, Stavanger, Norway) and the Q-CPR® software from the MRx defibrillator (Philips Medical Systems, Andover, USA), see Figure 4.

A crossover simulation study with the participants being randomised to start external chest compressions positioned either from-the-side or over-the-head of the manikin. Participants (n=15) were asked to perform external chest compressions on a Resusci Anne®Simulator manikin for a period of two minutes from one position and after a two minute rest period performed another two minute period of external chest compressions from the other position . During normal use Q-CPR® defaults to providing audio and visual feedback, however for the purposes of this study these audio and visual cues were disabled.



(a) (b) (c)

Figure 4. The experimental setup (a) the Laerdal Skill Reporter software (b) Resusci Anne® manikin with central Q-CPR® puck (c) The MRx defibrillator

Study participants

Fifteen participants were recruited from St John New Zealand (Auckland and Christchurch). All participants were currently employed as paramedics (Intermediate Life Support paramedic n = 8, Intensive Care Paramedic n = 7) working in the emergency ambulance sector. All participants had undergone continuing clinical education within the last two years that included cardiac arrest management training and were familiar with both the over-the-head and from-the-side CPR techniques.

Ethics and regulatory approval

The study was approved by the university ethics committee and registered with St John. All participants gave written consent.

Quality of CPR metrics

Data was simultaneously captured from both the LSR and Q-CPR. The data was analysed using Laerdal PC Skill Reporting System software, version 2.4.1 (Laerdal Medical Corporation, Stavanger, Norway) and the Q-CPR software from the MRx defibrillator (Philips Medical Systems, Andover, USA). Both software programmes recorded and automatically calculated: the session duration, total compressions delivered, compression rate, compression depth, compressions with adequate and inadequate depth, compressions with inadequate hand release (leaning) and the duty cycle. The duty cycle is the time spent compressing the chest as a proportion of the time between the start of one cycle of compression and the start of the next and thus reflects the active pressure on the chest.

Data from the Q-CPR was exported to an external memory card and viewed using the Philips Heart Start Event Review Pro version 4.2.1.0 (Flexera Software Inc, Schaumburg, Illinois, USA). The data from the manikin was viewed directly using the Laerdal PC Skill Reporting System software.

Statistical analysis

The CPR performance data from the Laerdal Skill Reporter software and the Philips Heart Start Event Review Pro was exported and saved as a portable document format file. The data was subsequently transferred to an Excel spread sheet (Microsoft, Redmond, WA, USA) and analysed using SPSS version 20 (IBM, New York, NY, USA). The external chest compression quality data was analysed with the two-tailed paired *t*-test with a value of $p<0.05$ considered to be statistically significant.

Results

Fifteen participants participated in the study; their demographics are described in Table 7.

Table 7. Participant demographics

	Male (n=9)	Female (n=6)
Years practicing	10.1 (8.5)	12.8 (8.1)
Weight (kg)	89.4 (17.9)	70.0 (5.1)
Height (cm)	181.3 (7.6)	171.3 (5.4)
Arm Length (cm)	59.4 (4.1)	55.5 (3.1)
Shoulder-to-knee length (cm)	97.4 (5.5)	92.3 (2.1)

mean (SD).

From-the-side CPR quality

For chest compressions performed from-the-side, simultaneously recorded from the LSR and Q-CPR devices, there was no significant difference in the recorded number of compressions performed in two minutes, the compression rate, the number of compressions with adequate depth and compressions with leaning (Table 8).

Table 8. Chest compressions performed from-the-side.

	LSR mean (±SD)	Q-CPR® mean (±SD)	Mean difference (95% CI)	*p* value
Number of compressions in 2 minute episode	223.9 (±23.0)	223.7 (±23.5)	0.20 (-0.36-0.76)	0.46
Compression rate (compressions per minute)	111.8 (±11.5)	111.7 (±11.6)	0.10 (-0.06-0.26)	0.20
Total compressions of adequate depth	202.3 (±58.6)	205.7 (±58.5)	-3.4 (-7.5-0.60)	0.09
Average compression depth (mm)	56.1 (±5.2)	51.9 (±5.6)	4.2 (2.18-6.35)	0.001*
Compressions with leaning	49.1 (±90.4)	31.7 (±51.9)	17.4 (-22.82-57.62)	0.37
Duty cycle (%)	44.9 (±4.6)	39.6 (±5.6)	5.3 (3.63-6.91)	<0.0001*

LSR = Laerdal Skill Reporter, Q-CPR® = Quality CPR puck system *$p<0.05$ significant

There was a significant difference in average depth of compression (mean difference = 4.2mm, p=0.001) and duty cycle (mean difference = 5.3%, p<0.0001).

Over-the-head CPR quality

For OTH chest compressions there was no significant difference in measurement between the LSR and Q-CPR® devices for the compression rate, the number of compressions with adequate depth and compressions with leaning (Table 9).

A significant difference was demonstrated in the number of compressions performed in two minutes (mean difference = 0.60, p=0.023). There was also a significant difference for the average depth of compression (mean difference = 5.9mm, p<0.0001). Additionally a significant difference was demonstrated for the duty cycle (mean difference = 4.5%, p<0.0001).

Table 9. Chest compressions performed over-the-head.

	LSR mean (±SD)	Q-CPR® mean (±SD)	Mean difference (95% CI)	*p* value
Number of compressions in 2 minutes	227.7 (±23.5)	227.1 (±23.4)	0.60 (0.09-1.10)	0.02*
Compression rate	113.5 (±11.8)	113.1 (±11.2)	0.33 (-0.08-0.68)	0.06
Total compressions of adequate depth	214.7 (±29.7)	213.5 (±59.3)	1.2 (-30.63-33.17)	0.93
Compression depth (mm)	57.3 (±4.7)	51.3 (±6.3)	5.9 (3.67-8.20)	<0.0001*
Compressions with leaning	74.1 (±97.8)	43.7 (±68.6)	30.33 (-27.84-88.50)	0.28
Duty cycle	44.5 (±4.1)	40.0 (±4.4)	4.5 (2.95-5.99)	<0.0001*

LSR = Laerdal Skill Reporter, Q-CPR® = Quality CPR puck system *p<0.05 significant

Leaning and depth of compression measurement

There was no significant difference in the identification of leaning by the LSR and Q-CPR devices. Both devices indicated that leaning was a common feature of compressions with greater than 60 % of CPR sessions having an incidence of leaning exceeding 1%. In approximately 20% of the

CPR sessions leaning featured in greater than 20% of the total compressions performed.

Additional analysis of the data revealed that the mean difference in the depth measured between the LSR and Q-CPR devices increased when leaning was a feature of chest compressions. There was a positive correlation between the mean difference in the depth measurements with the incidence of leaning ($R^2 = 0.8115$), Figure 5.

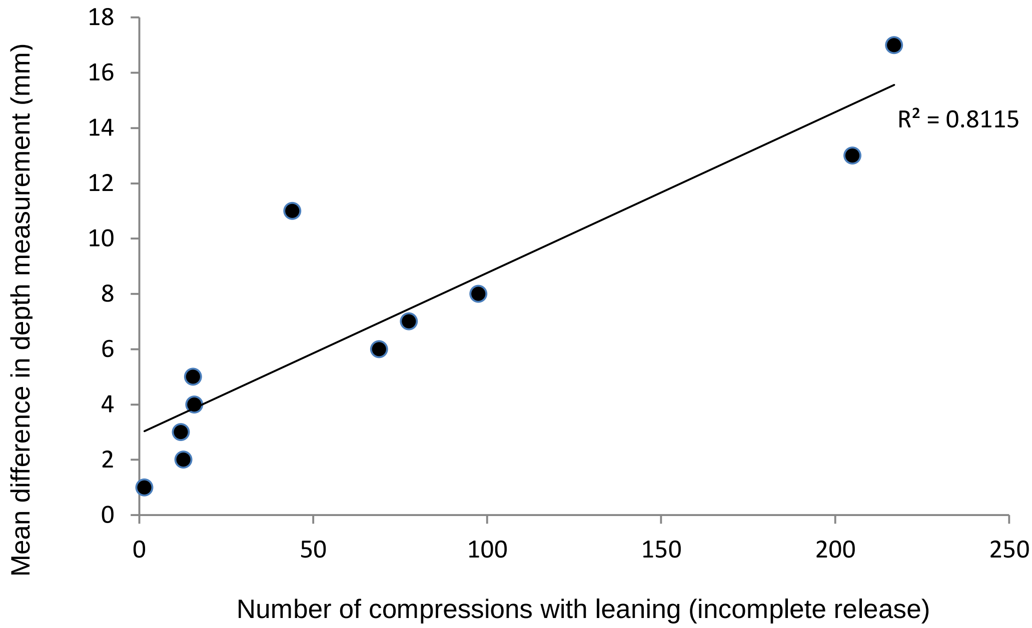


Figure 5. The association between mean difference in measurement of depth (mm) when chest compression depth is measured by the Laerdal skill reporter and the Q-CPR devices.

Discussion

The principle finding of this study is that there was no significant difference in the majority of chest compression quality metrics measured between the LSR and the Q-CPR® devices. However, there were significant differences in the measurement of duty cycle and also the depth of compressions between the two devices. These differences were observed to increase with an increasing incidence of leaning.

One of the primary goals during CPR is to maximise coronary perfusion pressure (CPP). In the absence of technology that facilitates easy measurement of CPP, focusing on metrics of high performance CPR may act as a proxy for maximising CPP (Meaney, et al., 2013). The American Heart Association has identified five components of high performance CPR: chest compression rate, chest compression depth, chest recoil (residual leaning), chest compression fraction and ventilation (Meaney, et al., 2013). Uniform reporting of CPR variables has been proposed for both quality improvement and clinical trials which adds episode duration, compressions delivered per minute, compression duty cycle and further evaluates the chest compression fraction by evaluating the perishock pauses (Kramer-Johansen, et al., 2007). The LSR and Q-CPR® devices measure metrics of CPR, however the LSR is limited in that it can only measure these in a training setting whereas Q-CPR® can be utilised in both the training and clinical settings.

In this study there was no significant difference in measurement of the majority of CPR (OTH or FTS) metrics when measured concurrently by LSR and Q-CPR®. For chest compressions performed FTS there was no significant difference in measurement of the total number of compressions performed in two minutes between LSR and Q-CPR®. Conversely when compressions were performed OTH there was a statistically significant difference in this measurement between the LSR and Q-CPR® devices. The mean difference between the devices was, however, only 0.6 compressions in the two minute period. Whilst this difference is statistically significant ($p = 0.02$), a difference of 0.6 compressions over a two minute period is not likely to be clinically important. The difference could possibly be due to the Philips Heart Start Event Review Pro software used to analyse the Q-CPR® data having the capacity to select and define a finite time period within much narrower limits than the LSR device.

The compression metrics of compression depth and duty cycle both exhibited a significant difference when measured by the two devices. The differences were observed when chest compressions were performed in both positions; from-the-side and over-the-head. The Q-CPR® device measured compression depths that were less than those measured by the LSR, 5.9mm and 4.2mm for OTH and FTS positions respectively. The Q-CPR® device uses an accelerometer which measures the sternal to spine displacement directly whereas the LSR manikin-based technology measures vertical displacement of the chest compression plate using a sliding potentiometer. The prototype of Q-CPR® has been previously compared against the LSR by Aase and Myklebust (2002) who showed a mean difference in depth measurement of only 1.6mm. In our study the mean difference in measurement between the two devices is approximately three times greater than previously reported by Aase and Myklebust. The difference may be due to the heterogeneity of the paramedic performance, including leaning incidence, which is more likely to be representative of paramedic practice as opposed to the original single case study described by Aasw and Myklebust (2002). Accurately measuring depth of compression is essential as each 5mm increase in chest compression depth has been shown to improve survival rates (odds ratio = 1.29) and is a focus of the 2010 Resuscitation Guidelines (Vadeboncoeur, et al., 2014). Real-time feedback on the depth of compression has been shown to be important in facilitating the achievement of an adequate depth of compression in training and clinical practice (Kramer-Johansen, et al., 2007; Meaney, et al., 2013; Travers, et al., 2010)

The 2010 Guidelines for CPR and ECC recommend a minimum depth for chest compressions in the adult patient of greater than 50mm (Travers, et al., 2010). A strong association between survival outcome and increased compression depth has been demonstrated (Edelson, et al., 2006; Kramer-Johansen, et al., 2006). Compression depths of less than 38mm have been shown to reduce rates of return of spontaneous circulation (ROSC). Stiell et al (2012) found that the maximum survival was associated with a depth of 45.8 mm followed by a decline in survival with depths of compression that exceeded 50 mm, which conflicts with the 2010 Guidelines. Conversely, more recently, a minimum compression depth of 51mm has been shown to improve outcomes for out-of-hospital cardiac arrest victims (Vadeboncoeur, et al., 2014).

Analysis of the compression depth and leaning data identified a positive correlation between the mean difference of compression depth recorded between the LSR and Q-CPR® devices and the degree of leaning exhibited in the CPR session, (Figure 5). As leaning increases there is an increase in the mean difference of measurement of compression depth between the two devices. Leaning occurs when the person performing the chest compressions exerts residual pressure on the chest at the end of the compression which does not allow complete chest wall recoil (Meaney, et al., 2013).

The use of an accelerometer, such as found in the Q-CPR® puck, has been shown to significantly underestimate the chest compression depth when a manikin is positioned on a mattress (Perkins, Kocierz, Smith, McCulloch, & Davies, 2009). The reason offered is that the accelerometer does not take into consideration the compression of the mattress, hence will underestimate the depth of chest compression. The use of dual accelerometers, one on top of the chest and one on top of the mattress, in this setting has been shown to improve chest compression depth measurement (Oh et al., 2012). This may give some insight to the observation that the mean difference in chest compression depth increases with increasing incidence of leaning. Leaning occurs when there is incomplete recoil of the chest wall to the normal anatomical level at the end of the chest compression. As depicted in Figure 6, if the chest was compressed 50mm from the normal anatomical position in the presence of a residual depth of 5mm due to leaning, the accelerometer would detect a net movement of only 45mm. In order to achieve a measured vertical depth of 50mm in the presence of 5mm of leaning the chest would need to be compressed to a depth of 55mm.

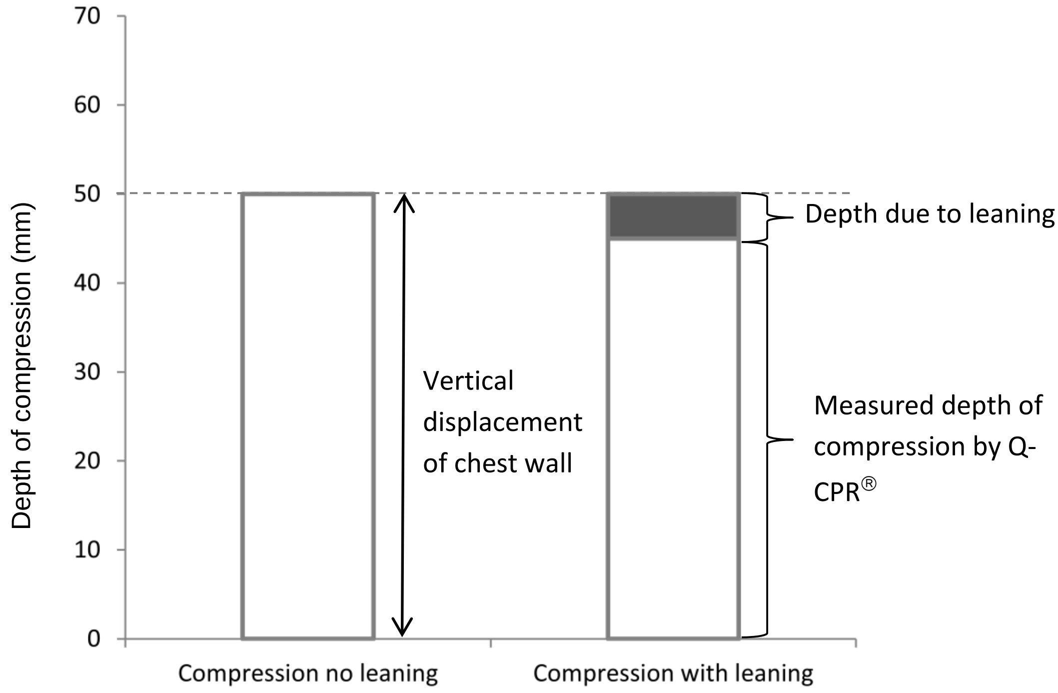


Figure 6. Proposed model of the influence of leaning on the measured depth of compression using the Q-CPR® puck.

Krammer-Johansen et al (2007) suggest that leaning is reported as a simple binary measure in which the percentage of the compressions with leaning from the entire CPR session is calculated. In the current study the LSR identified 27% of all compressions exhibited leaning whereas the Q-CPR® device identified 17%. This difference may be due to the LSR recording leaning as displacement of the chest plate from its normal position whereas the Q-CPR® device utilises a force meter that identifies leaning when there is a residual force of 2.5kg or more on the Q-CPR® puck. The LSR identified 53% of CPR sessions (complete simulation events) as having compressions with leaning, whereas the Q-CPR® device identified 67% of CPR sessions as having leaning. Fried et al (2011) analysed Q-CPR® data from 108 in-hospital cardiac arrests and found leaning was present in 91% (98 out of 108) of cases and that 12% of all compressions exhibited leaning. Animal studies have shown that leaning reduces venous return and cardiac output subsequently reducing coronary and cerebral perfusion (Zuercher et al., 2010). Whilst many human studies show high incidences of leaning there is a dearth of research relating leaning to outcomes (Fried, et al., 2011; Niles, Nysaether, et al., 2009; Niles, et al., 2011).

During this study the audio-visual feedback from the Q-CPR® device was disabled. The Q-CPR® device provides an audio feedback prompt that instructs the person performing chest compressions to release fully in the event that leaning is detected, thus potentially improving the accuracy of depth estimation. In clinical practice the audio feedback can be turned off; this practice may result in substantial misrepresentation of the actual depth of compression where there is concurrent leaning.

The other CPR metric in this study that showed a significant difference in measurement between the LSR and Q-CPR® was the duty cycle, Tables 8 and 9. The duty cycle, which is time spent compressing the chest as a proportion of the time between the start of one cycle of compression and the start of the next, reflects the active pressure on the chest, whether mechanical or by hand. The reason for this difference (FTS = 4.5% difference, OTH = 5.3% difference) is unclear but may be related to the influence of the different mechanisms for detection of leaning between the LSR and the Q-CPR® devices. Current evidence on the optimum duty cycle is limited and thus it is unclear whether the observed difference in measurement of duty cycle, approximately 5%, is clinically important. Previous Guidelines have suggested that the duty cycle should be less than 50% (2005 International Consensus on Cardiopulmonary Resuscitation and Emergency Cardiovascular Care Science with Treatment Recommendations. Part 2: Adult basic life support, 2005) with animal studies suggesting an optimal duty cycle of 40%. Out-of-hospital cardiac arrest studies have reported typical duty cycle means of 42% (Kramer-Johansen, et al., 2006; Wik, et al., 2005).

The paramedic performance of chest compressions in this study met the 2010 International Liaison Committee on Resuscitation (ILCOR) Consensus on Science and Treatment Recommendations for all CPR metrics measured except for leaning. (Koster, et al., 2010). The recommendation is that leaning should be minimised during chest compressions, although the 2010 Guidelines do not quantify the degree of leaning, if any, that is acceptable (Meaney, et al., 2013; Travers, et al., 2010). In this study over a third (37%) of the CPR sessions had leaning in less than one percent of all chest compressions performed, however in approximately 20% of the CPR sessions greater than 20% of all compressions exhibited leaning. These results are similar to other studies that have shown significant incidence of leaning by paramedic and medical staff (Fried, et al., 2011). This supports the notion that the correction of leaning should be a future key education strategy and suggests that the use of a device that identifies and provides corrective feedback on leaning should be used in a clinical setting.

Limitations

This study does not serve to validate the Q-CPR® or LSR as a measurement tool for quality CPR parameters but serves to compare the data generated by these two devices as they concurrently measure a CPR session.

There are inherent differences in the technologies associated with accelerometer and potentiometer based distance measurement devices.

This study was performed in a simulated environment on a manikin and as such they may not be directly generalisable to the clinical setting. The demographics of the paramedics, specifically the practicing level and years of practice may not necessarily be representative of the New Zealand paramedic cohort.

Conclusion

When Q-CPR® and the LSR are compared as tools for the measurement of quality parameters for chest compressions there is no significant difference for the majority of chest compression metrics measured in this study. There is a significant difference in the measurement of duty cycle, however the magnitude of this difference is very unlikely to be clinically relevant. There is also a significant difference in depth of compression measurement between the LSR and Q-CPR® devices, which increases with increasing incidence of leaning. The Q-CPR® device is an appropriate alternative to using LSR as a tool for assessing paramedic chest compression performance during CPR training. Q-CPR® has the added advantage of being able to provide corrective feedback during training and clinical resuscitation episodes and to provide CPR performance metrics for later review. When using the Q-CPR® device disabling the voice feedback which corrects leaning is not recommended. Finally paramedics performed well, consistent with the 2010 Guidelines, across the quality of CPR measures in this study. The 2010 Guidelines message of 'push hard and fast' appears to be translated into New Zealand paramedic practice.

Conflict of Interest

There are no conflicts of interest to declare.

Acknowledgements

We thank the paramedics from St John, New Zealand, who participated in this study and performed CPR expertly and Priya Parmar who provided biostatistical expertise.

.

CHAPTER 4

THE EFFECT OF PARAMEDIC POSITION, EITHER POSITIONED FROM-THE-SIDE OR OVER-THE-HEAD, ON EXTERNAL CHEST COMPRESSION QUALITY.

Overview

The over-the-head (OTH) chest compression technique was introduced as a solution to performing cardiopulmonary resuscitation (CPR) in confined spaces and for a single-rescuer ventilating with a manual bag ventilator. A few studies have evaluated OTH and from-the-side (FTS) CPR with variable results. No studies have been identified that have evaluated OTH compressions performed for extended periods subsequent to the introduction of the 2010 Resuscitation Guidelines.

Methods: A standardised cardiac arrest simulation using the Resusci Anne® manikin was used. Paramedics (n=30) were paired and randomised so that one performed OTH compressions and the other FTS compressions for the duration of the simulation. The paramedic performing chest compressions alternated every cycle, stopping after a total of ten cycles. After a fifteen minute rest period the paramedics crossed over positions and repeated the simulation. The quality of CPR was measured by Q-CPR® with audio-visual feedback disabled.

Results: There were no significant differences between OTH and FTS for all quality variables measured. The cycle length, average compression rate, duty cycle, no-flow period, chest compression fraction and ventilation rate all met the 2010 Guidelines. Leaning occurred in OTH 19.3%, FTS 19.0% (p= 0.916) of all compressions, and the mean depth of compression (OTH 45.7±7.5mm, FTS 46.1±7.2mm, p=0.454) was less than the >50mm recommended.

Conclusion: The position of the paramedic performing chest compressions, OTH or FTS, does not influence the quality of CPR performed on a manikin. For two-rescuer CPR the composite technique, where the paramedic that is positioned at the head performs OTH CPR, is an effective alternative to the traditional method of performing CPR FTS. Further education with regard to depth of compression and leaning is warranted.

Introduction

The global incidence of out-of-hospital cardiac arrest (OHCA) treated by emergency medical services (EMS) is estimated to be in the range of 50 to 55 per100 000 person-years (Travers, et al., 2010). In New Zealand the incidence of OHCA treated by EMS has been previously reported for the Wellington region as 36 per 100 000 person-years (Robinson, et al., 2010). The 2010 Resuscitation Guidelines recommend that, for adult cardiac arrest victims, chest compressions should be performed at a rate of at least 100 per minute, at a depth of greater than 50mm, allowing the chest to completely recoil between compressions and minimising interruptions to chest compressions. The ratio of chest compressions to ventilations should be 30:2, unless the patient has an advanced airway (endotracheal tube) in place. In such cases where an endotracheal tube is in place, compressions should be performed continuously with ventilations occurring at a rate of 8 to 10 ventilations per minute.(Sayre, Koster, et al., 2010; Travers, et al., 2010).

In the New Zealand pre-hospital environment the norm is for a responding EMS to have a crew of two paramedics. The term paramedic is used generically to describe ambulance staff. Paramedics commonly perform external chest compressions from-the-side (FTS) and/or from over-the-head (OTH). The OTH position is utilised by one paramedic in the initial phase of resuscitation whilst the second paramedic performs other interventions such as establishing intravenous access, preparing for airway management tasks and administering pharmaceutical agents (Maisch, et al., 2010). The OTH position for performing CPR was introduced in the 1990’s as a solution to performing CPR in a confined space and as a technique allowing a single rescuer to use a manual bag valve mask ventilator during resuscitation (Bollig, et al., 2007).

Several studies comparing single-rescuer OTH to single-rescuer FTS CPR have been reported (Bollig, et al., 2007; Handley & Handley, 2004; Hupfl, et al., 2005; Maisch, et al., 2011; Perkins, et al., 2004). These studies generally support the use of OTH CPR as an alternative when single-rescuer FTS CPR could not be performed. However there are several limitations in the previous studies; they all investigated CPR where chest compressions were performed for a short duration (2-3 minutes), studies exhibited heterogeneity in regards to the type and number of participants, the CPR quality metrics reported, the ventilation : compression ratio and types of ventilation adjuncts used were inconsistent. Additionally very few two-rescuer OTH CPR studies have been reported, and the studies identified reported inconsistent results (Brucke, et al., 2007; Handley & Handley, 2004; Maisch, et al., 2010). Furthermore the governing resuscitation guidelines used were not identical across the studies.

The resuscitation guidelines are published every five years after extensive consideration and peer review of contemporary resuscitation science (Field et al., 2010). One of the points of heterogeneity in a number of studies was that they were not governed by the same resuscitation guidelines. Furthermore, none of the studies selected for review have investigated the effect of the paramedic performing external chest compressions, OTH or FTS, on the quality of CPR following the introduction of the 2010 Resuscitation Guidelines. The key changes between the 2000 and 2010 Resuscitation Guidelines are a change from 15:2 to 30:2 for the compression and ventilation ratio, a greater emphasis on uninterrupted chest compressions, and a de-emphasising of ventilation; the ‘push hard and fast’ campaign (Travers, et al., 2010)

The purpose of this simulation study was to investigate the effect that the position of the paramedic performing external chest compressions, OTH or FTS, had on the quality of CPR subsequent to the introduction of the 2010 Resuscitation Guidelines.

Methods

Study design

The study was conducted in the Paramedicine Skills Laboratory (Taiwhanga pukenga) at the Auckland University of Technology. The research sought to determine if, for an individual, being positioned FTS or OTH whilst they perform chest compressions made a significant difference to CPR quality. The CPR quality parameters reported are consistent with uniform reporting consensus statements previously published (Kramer-Johansen, et al., 2007; Meaney, et al., 2013).

A two-rescuer composite CPR technique was used with the paramedic positioned at the head performing OTH chest compressions and the paramedic position at the side performing FTS chest compressions, as described by Brucke et al (2007). Analysis of CPR quality, including chest compression rate, depth, rescuer leaning (incomplete chest recoil), ventilation rate, perishock pauses and chest compression fraction, was undertaken in a simulated environment. The participants for the study were paramedics employed within the pre-hospital sector. The protocol of the study was designed to emulate the typical context of an ambulance crew of two paramedics attending a collapse and performing CPR as a team performing two-rescuer CPR for a period of 20-25 minutes within the framework of the 2010 Resuscitation Guidelines.

Participants worked in pairs and managed a standardised simulated cardiac arrest, following the 2010 Guidelines. The duration of the simulation was approximately 20-25 minutes; the time required for performing 10 cycles of CPR as each cycle was approximately 2 minutes in duration. A standardised (pre-programmed) simulated scenario was used so that each participant experienced the same scenario. The Resusci Anne®Simulator had an endotrachael tube inserted prior to the simulation to avoid airway management being a confounder, had ECG monitoring leads in place and had an initial rhythm of ventricular fibrillation which reverted to sinus rhythm after the 10th DC shock. The participants were instructed to stop CPR after the manikin simulated signs of return of spontaneous circulation. The FTS and OTH positions are shown in Figure 7.

(a) (b)

Figure 7. Chest compression performed (a) over-the-head of the manikin or (b) from-the-side.

Participants worked in pairs and were randomly allocated to the role of Rescuer 1 or Rescuer 2, see Figure 8. Randomisation was performed using odd-even allocation from a list of random numbers generated using SPSS (SPSS Inc, IL, USA).

Consistent with 2010 Guidelines the person performing the chest compressions changed every two minute cycle. The two minute cycles of CPR continued for 20-25 minutes, thus during one simulated event each participant performed a total of five cycles of compressions with one rescuer dedicated to performing compressions from-the-side and the other rescuer performing compressions over-the-head for the duration of the simulation. At the conclusion of the simulation the participant rested for 15 minutes and then repeated the simulation crossing over position.

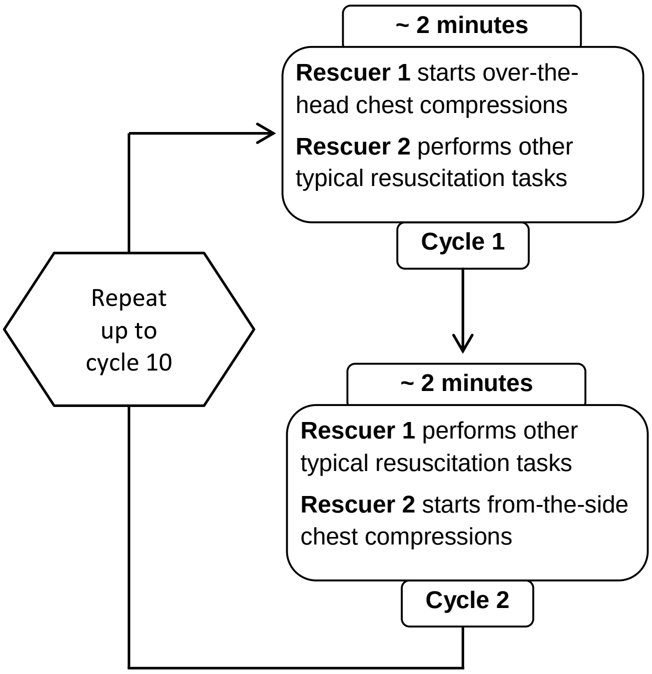


Figure 8. Study Design. The participants (pair) were randomised to Rescuer 1 or Rescuer 2, and then Rescuer 1 was randomised to start chest compressions either positioned over-the-head or from-the-side.

Study participants

Thirty participants were recruited from St John New Zealand (Auckland and Christchurch). All participants were currently employed as paramedics (Intermediate Life Support Paramedics n = 17, Intensive Care Paramedics n = 13) working in the emergency ambulance sector. The recruitment was restricted to a minimum practice level of Intermediate Life Support (ILS) paramedic as the study included inserting an intravenous cannula and administering standard cardiac arrest drugs which is not within the scope of practice of paramedics practising at a scope of less than ILS.

All participants were familiar with OTH and FTS external chest compression techniques as both are routinely used when managing a cardiac arrest. All participants had undergone continuing clinical education within the last two years that included cardiac arrest management training and participants gave written consent.

The number of participants chosen for this study (n=30) is based on a previous similar study which calculated that 20 participants were needed to demonstrate a 10% difference in chest compression depth at a significance level of 0.05 with 80% power (Perkins, et al., 2004).

Data collection

Data for CPR performed FTS and OTH was captured using the Q-CPR® software from the MRx defibrillator (Philips Medical Systems, Andover, USA). The Q-CPR® waveforms were occluded and the audio disabled so that the participants were blinded to their performance. Q-CPR® was used as it is a CPR quality feedback system that is integrated into a defibrillator enabling use in both simulated and clinical settings. In addition Q-CPR® is unique in that it provides real-time audio-visual corrective feedback and enables subsequent analysis of CPR quality parameters, including depth of compression, which is temporally synchronised with ECG and defibrillation.

Data from the Q-CPR® was exported to an external memory card and viewed using the Philips Heart Start Event Review Pro version 4.2.1.0 (Flexera Software Inc, Schaumburg, Illinois, USA). A CPR event consisted of ten cycles. Each cycle was approximately 2 minutes in duration, with each cycle representing the time between consecutive defibrillation. The Event Review Pro software automatically calculated for each cycle: the session duration, total compressions delivered, compression rate, compression depth, compressions with adequate and inadequate depth, compressions with inadequate hand release (leaning), duty cycle and no-flow time. Compression fraction and perishock pauses for each defibrillation event were also calculated.

The ventilation frequency was extracted from Resusci Anne®Simulator data recorded by the Laerdal Skill Reporter during one cycle of CPR (cycle 3). Demographic data of the participants was also recorded including weight, height, body mass index (BMI), arm length, shoulder-to-knee length, gender, age, length of time practising and practice level (ILS or ICP). Arm length was measured from acromion to the anterior crease of wrist on palmar flexion and the shoulder-to-knee length was measured, with the participant standing, from the acromion to the superior patella border.

Data analysis

The CPR performance data, for both OTH and FTS, was exported to and analysed by the Philips Heart Start Event Review Pro, subsequently being saved as a portable document format file. The data was transferred to an Excel spread sheet (Microsoft, Redmond, WA, USA) and analysed using SPSS version 20 (IBM, New York, NY, USA). The mean for all variables for the entire CPR (20 to 25 minutes) was compared between FTS and OTH using a two-tailed paired *t*-test with a value of $p \leq 0.05$ considered to be statistically significant.

Additionally for both positions the change in mean for compression rate, depth, incidence of leaning, no-flow time and duty cycle, between each cycle of CPR (approximately 2 minutes) was analysed using a general linear model for repeated measures. Again a p value of ≤0.05 was considered to be statistically significant.

The associations between participant weight, height, BMI, arm length, knee-to-shoulder length and CPR metrics was also assessed using Pearson's correlation coefficient (r). The magnitudes of any associations was described as trivial (0.0 – 0.1), small (0.1-0.3), moderate (0.3-0.5), large (0.5-0.7), very large (0.7-0.9), or extremely large (0.9-1.0) (Hopkins, Marshall, Batterham, & Hanin, 2009).

Ethics and regulatory approval

The study was approved by The Auckland University of Technology Ethics Committee (AUTEC Ref: 13/10) and registered with St John (Ref: 009). All participants gave written consent.

Results

Thirty participants took part in the study; their demographics are described in Table 10.

Table 10. Participant demographics

		Male (n=23)	Female (n=7)
Years practising		10.5 (7.8)	12.1 (5.6)
Weight (kg)		89.4 (17.9)	67.9 (7.3)
Height (cm)		180.4 (7.2)	170.1 (5.8)
BMI (kg.m^{-2})		27.2 (4.0)	23.5 (2.7)
Arm Length (cm)		58.9 (3.9)	55.3 (2.9)
Shoulder-to knee-length(cm)		96.6 (4.9)	92.4 (1.9)
Age	<20 years	0%	0%
	21 – 30 years	10%	7%
	31 – 40 years	43%	10%
	41 – 50 years	23%	3.5%
	51 – 60 years	0%	3.5%
Practising level			
Intermediate Life Support		47%	10%
Intensive Care Paramedic		30%	13%

Parametric data are presented as mean (S.D.).
Categorical data are represented as percentage of total (%)

There was no significant difference in mean CPR quality between compressions performed OTH or FTS for all metrics measured, Table 11. The CPR metrics that met the 2010 Resuscitation guidelines included: the number of chest compressions performed in 2 minutes, compression rate, duty cycle, no-flow time and chest compression fraction. The depth of compression, the number of compressions exhibiting leaning and the ventilation rate did not comply with the recommendations for these metrics described in the 2010 Resuscitation Guidelines

Table 11. Difference in mean CPR quality metrics recorded over-the-head versus from-the-side.

External chest compression measure	Over-the-head (mean (SD))	From-the-side (mean (SD))	Mean difference (95% CI)	P value
CPR length of cycle(s)	126.7 (2.7)	126.1 (2.3)	0.60 (-0.35 – 1.55)	0.20
Number of compressions in 2 minutes	238.1 (11.7)	236.4 (11.2)	1.74 (-0.77 – 4.25)	0.17
Compressions rate (per minute)	115.3 (5.5)	117.3 (14.7)	-1.97 (-6.98 – 3.05)	0.43
Total compressions of adequate depth (per cycle)	197.0 (77.6)	199.8 (67.7)	-2.8 (-17.16 – 11.56)	0.69
Average compression depth (mm)	45.7 (7.4)	46.1 (7.2)	-0.39 (-1.43 – 0.66)	0.45
Number of compressions with leaning (per cycle)	45.9 (63.6)	45.1 (56.4)	0.74 (-13.56 – 15.04)	0.92
Duty cycle	41.0 (3.1)	41.4 (2.7)	-0.44 (-1.17 – 0.29)	0.23
Period of 'No-flow' time per cycle (s)	3.4 (1.1)	3.4 (1.1)	0.04 (-0.28 – 0.35)	0.82
Perishock pause (s)	3.6 (1.4)	3.5 (1.3)	0.1 (-0.10 – 0.31)	0.32
Chest compression fraction	97.3 (1.1)	97.3 (1.1)	-0.01 (-0.17 – 0.15)	0.87
Number of ventilations per cycle	13.9 (3.2)	14.6 (3.1)	-0.7 (-1.5 – 0.1)	0.10

CI = confidence interval; SD = standard deviation

Leaning was common and was exhibited in all participants. The severity of leaning exhibited by participants was arbitrary categorised, or rated, from zero to severe, Figure 9. There was high variability in the severity of leaning observed, sixteen participants had minimal leaning (leaning incidence of less than 10%), four participants had minor or moderate leaning and nine participants had severe leaning (leaning incidence of greater than 31%).

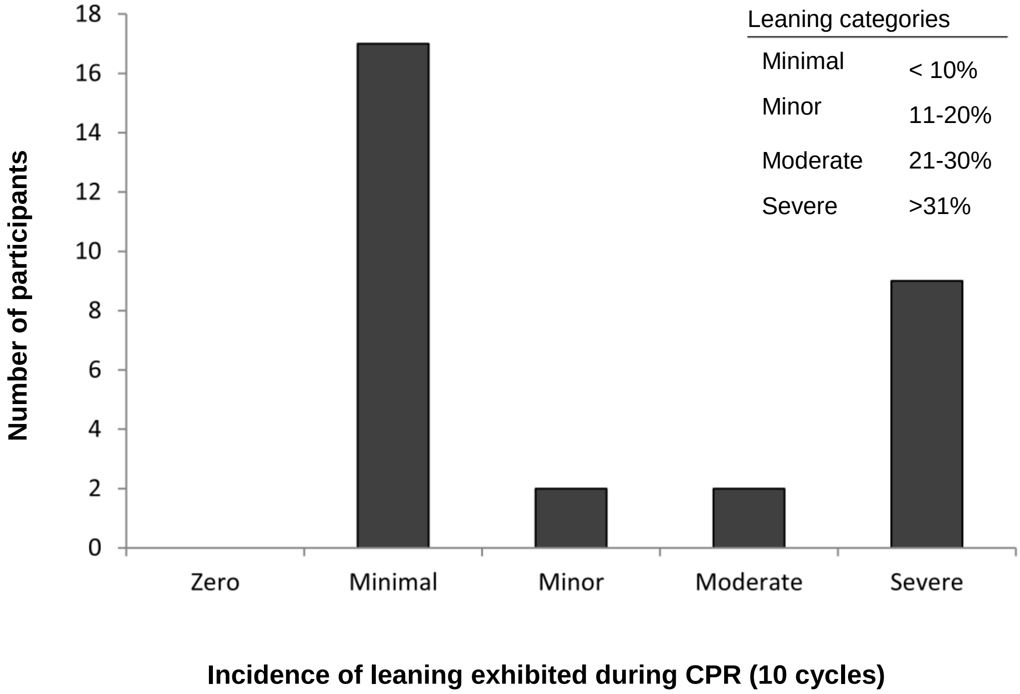


Figure 9. The incidence of leaning during the simulation (10 cycles of CPR) – the participant's incidence of leaning during the CPR performance was categorised as either zero, minimal, minor, moderate or severe.

Table 12 shows the mean difference in the observed performance of the listed CPR quality metrics for each successive time period (~2 min cycle of CPR) compared to the first. Compared to the first cycle there was no significant difference observed in the subsequent cycles for depth of compression (OTH: p=0.23, FTS: p=0.26), the incidence of leaning (OTH: p=0.32, FTS: p=0.67) and the duty cycle (OTH: p=0.23, FTS: p=0.24). There was a significant difference in compression rate over time for both positions; OTH (p=0.005) and FTS (p=0.003). The compression rate increased over time. The difference in compression rate became significant after the second cycle. The compression rate difference over time was between 1 to 2.4 compressions per minute for successive periods of CPR (cycles).

Table 12: The mean difference in CPR performance over time. The performance in each cycle (1 to 5) is compared to the performance in the first cycle for each position.

CPR metric	Cycle	OTH	P value	FTS	P value
Rate	1	-	-	-	-
(Compressions	2	1.07 (-0.22-2.35)	0.10	0.93 (-3.21-2.19)	0.14
per minute)	3	1.83 (0.55-3.12)	0.01*	1.8 (0.55-3.05)	0.01*
	4	1.53 (0.25-2.82)	0.02*	2.33 (1.08-3.59)	<0.0001*
	5	2.40 (1.11-3.69)	<0.0001*	1.93 (0.68-3.19)	0.003*
Depth of	1	-	-	-	-
Compressions	2	1.03 (0.11-1.95)	0.28	-0.33 (-1.28-0.61)	0.49
(mm)	3	0.63 (-0.29-1.55)	0.18	0.60 (-0.34-1.54)	0.21
	4	0.87 (-0.05-1.79)	0.07	0 (-0.94-0.94)	1.00
	5	0.60 (-0.32-1.52)	0.20	-0.37 (-1.31-0.58)	0.44
Leaning	1	-	-	-	-
(number of	2	-7.03 (-22.02-7.95)	0.35	-11.21 (-27.02-4.60)	0.16
compressions	3	-15.03 (-30.02—0.05)	0.05*	-9.31 (-25.12-6.50)	0.25
with leaning)	4	-3.47 (-18.45-11.52)	0.65	-8.12 (-23.99-7.64)	0.31
	5	-9.63 (-24.62-5.35)	0.25	-5.51 (-21.32-10.30)	0.49
No-flow time	1	-	-	-	-
(seconds per	2	0.41 (0.11-0.94)	0.41	0.60 (0.14-1.06)	0.01*
cycle)	3	-0.003 (-0.53-0.52)	0.63	0.29 (-0.17-0.75)	0.21
	4	-0.13 (-0.66-0.40)	0.99	0.03 (-0.43-0.48)	0.91
	5	-0.22 (-0.75-0.31)	0.12	-0.15 (-0.61-0.30)	0.51
Duty Cycle	1	-	-	-	-
(%)	2	-0.50 (-1.08-0.08)	0.09	0.03 (-0.54-0.61)	0.91
	3	-0.47 (-1.05-0.12)	0.12	-0.23 (-0.81-0.34)	0.42
	4	-0.63 (-1.22--0.05)	0.03*	-0.37 (-0.94-0.21)	0.21
	5	-0.53 (-1.12-0.05)	0.07	-0.53 (-1.11-0.04)	0.07

Values are mean difference (95% CI), **p* value ≤0.05 is significant, OTH: over-the-head, FTS: from-the-side, CPR: cardiopulmonary resuscitation

The associations between participant weight, height, BMI (body mass index), arm span, shoulder-to-knee length and CPR metrics were assessed using Pearson's correlation coefficient (r), Table 13. Using the scale previously described by Hopkins et al (2009) the magnitude of most of the associations are described as being either trivial or small. Compression depth demonstrated a moderate association with participant weight and shoulder-to-knee length for both OTH and FTS CPR. The magnitude of association between compression depth and participant height and arm length was also large, for both positions (Hopkins, et al., 2009).

Table 13. Association (Pearson correlation coefficient) between rescuer demographics and chest compression quality metrics

	Compression rate		Compression depth		Leaning		Duty cycle	
	OTH	FTS	OTH	FTS	OTH	FTS	OTH	FTS
Height	-0.013	-0.227	0.550	0.611	0.022	-0.010	0.096	0.157
Weight	-0.047	-0.094	0.433	0.485	0.222	0.127	0.304	0.318
BMI	-0.034	0.033	0.258	0.275	0.242	0.138	0.300	0.279
Arm length	0.084	-0.153	0.602	0.656	-0.098	-0.214	0.082	0.070
Shoulder-to-knee length	-0.249	-0.317	0.325	0.487	0.180	0.049	0.299	0.259

BMI: body mass index, OTH: over-the-head, FTS: from-the-side, magnitude of association scale (r) trivial: 0.0 – 0.1, small: 0.1-0.3, moderate: 0.3-0.5, large: 0.5-0.7, very large: 0.7-0.9, extremely large: 0.9-1.0

Discussion

The principle finding of this study is that the position of the paramedic performing chest compressions on a manikin, either from-the-side or over-the-head, does not cause a significant difference in any of the CPR quality metrics investigated. There are two key secondary findings; firstly that CPR performance did not deteriorate over time, compression rate was the only metric to demonstrate a significant difference over the 25 minute resuscitation scenario. Compression rate was seen to increase over successive cycles of chest compressions. Secondly there is a large association between compression depth and both arm length and height of the participant.

Chest Compression fraction (CCF) is defined as the proportion of CPR time spent providing chest compressions. Previous studies have demonstrated a relationship between increasing CCF and an increased survival from cardiac arrest (Christenson, et al., 2009; Vaillancourt et al., 2011). For OHCA due to non-ventricular fibrillation rhythms each 10% increase in CCF has been associated with an odds ratio for survival of 1.05 (95% CI: 0.99 – 1.12) (Vaillancourt, Everson-Stewart, et al., 2011) and 1.11 (95%CI: 1.01 – 1.21) when ventricular fibrillation is the presenting rhythm (Christenson, et al., 2009). The maximal rates of survival have been shown to be associated with a CCF value greater than 80% (Christenson, et al., 2009; Vaillancourt, Everson-Stewart, et al., 2011).

In this study no significant difference in CCF between OTH and FTS CPR was observed with a CCF of 97.3% for both positions. The CCF was substantially higher than reported in previous positional CPR manikin studies. Bollig et al (2007) reported CCF's for OTH of 50% and for FTS of 48% ($p=0.92$) and Maisch et al (2011) reported 74.2% for both OTH and FTS CPR positions. Maisch et al (2010) compared two-rescuer FTS CPR to single-rescuer OTH CPR and reported a CCF of 68.3% for OTH and 79.6% for FTS CPR positions ($p<0.01$). Brucke (2007) used a composite technique with alternating OTH and FTS CPR and reported a CCF of 83.9%. Large differences in CCF have also been reported in human OHCA studies. Wik et al (2005) reported a CCF of 52% and more recently Vaillancourt (2011) reported a CCF of 71%.

A possible reason for the low CCF reported in the earlier studies is that the 2000 Resuscitation Guidelines used recommended a compression to ventilation ratio of 15:2 compared to the more recent studies that used 30:2. The lower ventilation rate associated with the 30:2 ratio enables more time for chest compressions. Whilst the human studies will have a cross section of airway adjuncts used, most of the previous manikin studies have used simple airway adjuncts which necessitate a pause in chest compressions for ventilation. The advantage of using an advanced airway is that you can perform continuous chest compressions, as was the case in this study and the study by Brucke et al (2007). Another strategy that increases the CCF is the use of a manual defibrillator instead of an automated external defibrillator (AED), as we did in this study. The use of manual mode defibrillation has been reported to significantly reduce interruptions to chest compressions in the 30 seconds leading up to defibrillation and also shorten the pre-shock pause (Tomkins, Swain, Bailey, & Larsen, 2013).

The perishock pause is the time associated with rhythm analysis and defibrillation during which no chest compressions are being performed. This period is divided into the pre-shock and post-shock pauses which represent the time periods in which no chest compressions are being performed immediately before and after the delivery of the shock respectively, Figure 10. For each 5-second increase in perishock pause the odds of survival decreases by 18% and for every 5-second increase in pre-shock pause the odds of survival has been shown to by decrease by 14% (Cheskes et al., 2011). There was no significant difference in perishock pauses observed between OTH and FTS in this study (OTH: 3.6±1.4s; FTS: 3.5±1.3s). The duration of the pre-shock pauses observed were substantially shorter than those reported in other studies; Edelson et al (2006) reported median pre-shock pause of 15.3s and Cheskes et al (2011) reported a median pre-shock pause of 15.6s. The difference may be due to using the defibrillator in manual mode only in this study and may be due to differences between human and manikin studies. Tomkins et al (2013) previously demonstrated shorter perishock pauses when the defibrillator was used in manual mode compared to automatic mode.

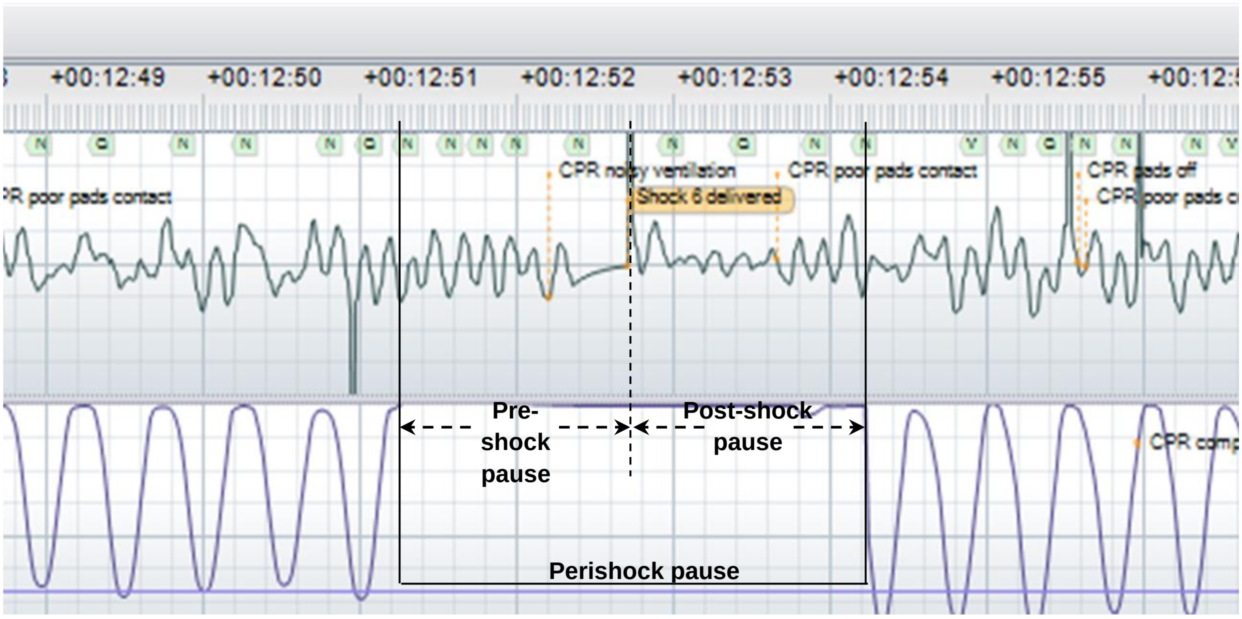


Figure 10. The perishock pause. In this example the perishock pause is 2.94s, pre-shock pause = 1.51s and post-shock pause = 1.43s (participant 9 OTH and 10 FTS).

In this study there was no significant difference in the number of compressions that exhibited leaning between OTH and FTS positions (p=0.92). A total of 71169 compressions were recorded (OTH: 35715, FTS:

35454) of which approximately 19% (13647 compressions) exhibited leaning. Eliminating leaning is an important CPR quality metric as leaning has been shown to increase intrathoracic pressure, decrease coronary perfusion pressure, myocardial blood flow and cardiac output (Niles, et al., 2011). Previous manikin studies comparing OTH to FTS CPR do not report a high incidence of leaning (Bollig, et al., 2007; Brucke, et al., 2007; Maisch, et al., 2011; Maisch, et al., 2010). Human studies, however, do report high incidence of leaning with greater than 90% of cases and 12 to 50% of all compressions exhibiting leaning (Fried, et al., 2011; Niles, Nysaether, et al., 2009)

In this study leaning was common with some degree of leaning being present in all cases. There was wide variability in the incidence of leaning, as reflected by the large standard deviation reported in Table 11. The leaning profile is consistent with that seen in human studies but not consistent with the findings of previous manikin studies investigating OTH CPR. A possible explanation for this may be the short duration of chest compressions performed and the inclusion of training prior to participation in the previous studies (Bollig, et al., 2007; Brucke, et al., 2007; Fried, et al., 2011; Maisch, et al., 2011; Maisch, et al., 2010; Niles, Nysaether, et al., 2009; Niles, et al., 2011).

There was no significant difference in the rate of ventilation between positions. The observed ventilation rates, approximately 7 ventilations per minute, were lower than recommended by the 2010 Resuscitation Guidelines; which recommends that when an advanced airway is in place ventilation should be delivered every 6 to 8 seconds to deliver ventilations at a rate of 8 to 10 per minute (Travers, et al., 2010).

Numerous studies have reported deterioration in CPR performance as a function of time, typically attributed to rescuer fatigue (Ashton, McCluskey, Gwinnutt, & Keenan, 2002; McDonald, Heggie, Jones, Thorne, & Hulme, 2013; Sugerman et al., 2009). In this study there was no significant difference in depth of compression, duty cycle, incidence of leaning and no-flow time between the first and subsequent cycles of CPR. These findings are consistent with a previous manikin study investigating fatigue in paramedics performing CPR over a ten minute period (Bjorshol, et al., 2011). Compression rate did demonstrate a significant difference over time for both positions, evident after the second cycle. The compression rate difference over time was an increase in rate of between 1 to 2.4 compressions per minute for successive cycles of CPR, which is not likely to have a clinical significance.

The association between rescuer demographics height, weight, BMI, arm length and shoulder-to-knee length, to CPR quality metrics (compression rate and depth, incidence of leaning and duty cycle) was also investigated. The magnitude of association between compression depth and participant height and also arm length was large, for both positions. A moderate association between compression depth and weight and duty cycle was observed. Other studies have found that there was a strong association between weight and depth of compression (Hasegawa, Daikoku, Saito, & Saito, 2014). One possible explanation for a lower magnitude of association between weight and depth of compression in this study is the relatively narrow range of the weight of participants (mean weight 83.9±16.1kg) compared to the Hasegawa et al (2014) study which included participants with a much lower body weight (50 - 75kg).

Limitations

The paramedic participants were not blinded to the purpose of the study and thus were aware that their CPR performance was being assessed. This may have influenced their performance. Likewise the manikin was intubated so that airway management was removed as a confounder. Airway management has been identified as one of the tasks that increases the no-flow time and decreases chest compression fraction (Wang et al., 2009).

The demographics of the participating paramedics, specifically the practising level and years of practice may not necessarily be representative of the New Zealand paramedic cohort. The mean experience of the paramedics was 10 years with all having significant experience in the clinical management of OHCA. Most of the paramedics had completed a tertiary qualification, the curriculum of which has a large emphasis on resuscitation and crew resource management. Hence the performance may not necessarily reflect that of all paramedics or other health professionals.

This study was performed in a simulated environment on a manikin which is devoid of the typical chaos and unpredictability associated with the clinical setting; as such the findings may not necessarily be directly generalisable to the clinical setting.

Conclusion

The position of the paramedic performing chest compressions, OTH or FTS, does not influence the quality of CPR performed on a manikin. For two-rescuer CPR the composite technique, where the paramedic that is positioned at the head of the manikin performs OTH CPR, is an effective alternative to the traditional method of only performing CPR FTS. The key messages of the 2010 Resuscitation Guidelines pertaining to compression rate, CCF, perishock pause and avoiding hyperventilation appear to be translated to paramedic practice, however the incidence of leaning and depth of compressions did not meet the guideline recommendations. Deterioration in CPR performance over time did not feature in this study. Human studies are needed to confirm the translation of these findings to clinical practice. Further education with regard to depth of compression and leaning is warranted.

Conflict of Interest

There are no conflicts of interest to declare.

Acknowledgements

We thank the paramedics from St John, New Zealand, who participated in this study and performed CPR expertly and Priya Parmar who provided biostatistical expertise.

CHAPTER 5

DISCUSSION AND CONCLUSION

Preface

This chapter summarises the key findings of the studies, outlining the effect of the position of the paramedic performing external chest compressions, from-the-side or over-the-head, on the quality of CPR. The limitations of the thesis are presented along with the opportunities for future research. The closing remarks state the conclusions of the thesis as a whole.

Discussion

The burden associated with cardiac arrest is significant both to the family and the community (Berdowski, et al., 2010; Grasner & Bossaert, 2013). Survival from cardiac arrest is dependent on many factors which are influenced by the complexities associated with the patient and the continuum of patient management which extends from the pre-hospital to the in-hospital environment. The Chain of Survival describes the importance of early and good quality CPR; the association between quality CPR and survival has been demonstrated by numerous studies previously (Abella, et al., 2005; Berg et al., 2001; Cheskes, et al., 2011; Christenson, et al., 2009; Gundersen, Nysaether, Kvaloy, Kramer-Johansen, & Eftestol, 2009). Meaney et al (2013) describes poor quality CPR as being a preventable harm and Travers et al (2010) highlights the need for developing a culture of high quality resuscitation, using a critical quality improvement philosophy that has a continuous cycle of measurement, benchmarking and gives opportunity for feedback and change. In light of these sentiments this study sought to investigate if the position of the paramedic, from-the-side (FTS) or over-the-head (OTH), influenced the quality of CPR performed.

Chapter 2 presents a synopsis of a literature review of studies published in peer-reviewed journals. The search of the literature revealed a dearth of published studies comparing the OTH and FTS positions for performing chest compression by working paramedics. Whilst the search identified 138 potential studies, only eight studies met the inclusion criteria. The International Liaison Committee on Resuscitation (ILCOR) traditionally use five levels of evidence (LOE) with the highest, LOE 1, being randomised controlled trials, or a meta-analysis of such. There were no randomised controlled trials, or meta-analyses identified (LOE 1). Likewise no LOE 2, LOE 3 or LOE 4 studies were found. All of the eight studies reviewed were LOE 5 manikin studies. By definition LOE 5 studies are those studies that are not directly related to the specific patient/population (e.g. different patient/population, animal models, manikin models).

The principle finding of this review was that in simulated conditions CPR performed OTH results in CPR quality similar to that observed when CPR is performed FTS. The studies suggest that it would be reasonable to use OTH CPR as an alternative to single-rescuer FTS CPR, particularly if ventilating using a Bag Valve Mask manual ventilation device (BVM). However there were significant limitations to many of the studies reviewed. Most studies only investigated chest compressions for a short duration, typically two minutes. There was also obvious heterogeneity in methods, participant skill/experience, quality parameters reported, the type of ventilation adjunct and the clinical CPR protocol used. Seven studies reported similar CPR quality between OTH and FTS CPR. Two studies compared two-rescuer FTS CPR to single-rescuer OTH CPR with conflicting results; one reported no difference in CPR quality, conversely the other reported inferior CPR quality with OTH CPR. Secondly, it appears that in simulation, two-rescuer CPR provides superior CPR quality than single-rescuer OTH CPR.

The heterogeneity and low number of studies identified for review made it difficult to conclusively determine the utility of using OTH CPR. The review highlighted the need for further manikin studies based on the 2010 Resuscitation Guidelines, assessing OTH CPR for longer periods, to investigate the influence that fatigue may have on CPR quality. As no human randomised controlled trials have been conducted it is not possible to conclusively comment on the translation of findings from the review into clinical practice. Further sufficiently powered studies, that use standardised reporting of CPR quality parameters, in which CPR is performed on human cardiac arrest victims, are needed to conclusively recommend the use of OTH CPR during clinical resuscitation.

The studies described in Chapter 2 utilised manikin-based technology, such as the Laerdal Skill Reporter (LSR), to measure the quality of CPR. The LSR is limited to reporting CPR quality from CPR that is performed exclusively on manikins so there is no capacity to use this device in a clinical context. Defibrillator technology has evolved over time and now many have CPR quality measurement tools incorporated as a standard feature of the device. The MRx defibrillator, commonplace in the pre-hospital clinical context, includes a puck-based accelerometer for measuring the quality of the CPR delivered. The intention was to use the MRx defibrillator with Q-CPR® as the device for measuring the quality of CPR performed by paramedics in this study. Minimising the differences between the simulated and real contexts has been shown to increase the veracity and authenticity of a simulation (Gormley, Sterling, Menary, & McKeown, 2012). Using the MRx defibrillator with Q-CPR® would also allow direct comparison between simulation and real contexts, if the study was to be repeated with humans. As no studies were identified that used Q-CPR® to compare OTH and FTS chest compressions, a study described in Chapter 3, was undertaken to compare the measurement of CPR quality metrics between the LSR to Q-CPR®.

Chapter 3 describes a crossover simulation study with external chest compressions being performed on a Resusci Anne®Simulator manikin. The compression variables were simultaneously measured by LSR and with Q-CPR®. This study sought to compare external chest compression data from the manikin-based LSR technology and the puck-based Q-CPR® technology to inform the suitability of using Q-CPR® as an alternative tool for assessing chest compression performance during CPR training. During normal use Q-CPR® defaults to providing audio and visual feedback, however for the purposes of this study these audio and visual cues were disabled so that the participants were blinded to their performance.

The principle finding of this study was that when Q-CPR® and the LSR are compared as tools, for the measurement of chest compression quality, there is no significant difference for the majority of chest compression quality metrics. There was a significant difference in the measurement of duty cycle (mean difference OTH: 4.5%; FTS: 5.3%, $p<0.0001$), however the magnitude of this difference is very unlikely to be clinically relevant. There was also a significant difference in depth of compression measurement between the LSR and Q-CPR® devices (mean difference OTH: 5.9mm, $p<0.0001$; FTS: 4.2mm, $p=0.001$). The mean difference in measurement of chest compression depth between the devices was observed to increase with an increasing incidence of leaning; with the Q-CPR® device reporting a shallower depth of compression compared to the LSR device. The magnitude of difference in measurement of chest compressions is likely to be clinically significant as each 5mm increase in chest compression depth has been shown to improve survival rates (odds ratio = 1.29) and is a focus of the 2010 Resuscitation Guidelines (Vadeboncoeur, et al., 2014).

Based on the results of this small study it is reasonable to suggest that the Q-CPR® device is an appropriate alternative to using LSR as a tool for assessing paramedic chest compression performance during CPR training. Q-CPR® has the added advantage of being able to provide corrective feedback during training and clinical resuscitation episodes. Additionally Q-CPR® enables the resuscitation event to be saved and exported so that the CPR performance metrics can be reviewed and analysed at a later time.

Based on these results Q-CPR® was used as the CPR quality measurement device for the main study of the thesis, described in Chapter 4.

Chapter 4 describes the main study of the thesis which involved 30 paramedics who worked in pairs managing a standardised cardiac arrest simulation. The rationale for this study was borne out of the low number of studies, that were highly heterogeneous and were without a clear consensus as to the utility of OTH CPR, identified in the literature review (Chapter 2). The composite technique for performing CPR, described by Brucke et al (2007), was used. The aim of this study was to compare OTH and FTS positions for performing chest compressions to identify if there was a difference in CPR quality between positions. The management of the cardiac arrest simulation was based on the 2010 Resuscitation Guidelines and was performed over a longer duration (20-25 minutes) compared to the previous studies (mean of 2 minutes).

The principle finding of this study was that the position of the paramedic performing chest compressions on a manikin, either FTS or OTH, does not cause a significant difference in any of the CPR quality metrics investigated. Specifically these included: chest compression rate, compression depth, duty cycle, incidence of leaning, perishock pause, chest compression fraction and ventilation rate. There are two key secondary findings; firstly that CPR performance did not deteriorate over the duration of the simulation, which was typically 22-25 minutes in total. Many studies conducted prior to the introduction of the 2010 Resuscitation Guidelines demonstrated significant deterioration in quality of CPR, in particular compression depth and rate, which has been attributed to rescuer fatigue (Foo, et al., 2010; Perkins, et al., 2004; Vaillancourt, Midzic, et al., 2011). Secondly, a large association between compression depth and arm length and also compression depth and the height of the participant was observed. Hence the conclusion of this study is that there is no difference in CPR quality between OTH and FTS positions, CPR performance does not deteriorate over time and that as arm length and/or height of the paramedic increase the depth of compression was also observed to increase.

Limitations of the thesis

The studies presented in the thesis were, at times, limited by methodological constraints and these should be taken into account when interpreting the results.

- This thesis does not serve to validate the Q-CPR® or LSR as a measurement tool for quality CPR parameters but serves to compare the data generated by these two devices as they concurrently measure a CPR session.

The paramedic participants were not blinded to the purpose of the study and thus were aware that their CPR performance was being assessed. This may have influenced their performance. Likewise the manikin was intubated so that airway management was removed as a confounder. Airway management has been identified as one of the tasks that increases the no-flow time and decreases chest compression fraction (Wang et al., 2009).

- The demographics of the participating paramedics, specifically the practising level and years of practice may not necessarily be representative of the New Zealand paramedic cohort. The mean experience of the paramedics was 10 years with all having significant experience in the clinical management of OHCA. Most of the paramedics had completed a tertiary qualification, the curriculum of which has a large emphasis on resuscitation and crew resource management. Hence the performance may not necessarily reflect that of all paramedics or other health professionals.
- This study was performed in a simulated environment on a manikin which is devoid of the typical chaos and unpredictability associated

with the clinical setting; as such the findings may not necessarily be directly generalisable to the clinical setting.

Future research opportunities

One of the potential limitations of the study was that it was conducted in a simulated setting. The MRx defibrillator with Q-CPR® that was used for data collection for the study is currently used in the pre-hospital clinical environment, thus one future research opportunity may be to replicate the study in this environment. Such a study could investigate the effect the position of the paramedic performing chest compression directly on the population of interest; those experiencing an out-of-hospital cardiac arrest. Replicating the study in the clinical environment may offer insight into the translation of simulation performance to the clinical setting.

The use of an advanced airway device, such as an endotracheal tube, is an option for management of the airway during OHCA (H. E. Wang & Yealy, 2013). Previous studies have identified that the placement of an endotracheal tube is associated with a reduction in chest compression fraction (Gray, Iyanaga, & Wang, 2012). In New Zealand the paramedic has three airway adjuncts in their scope of practice: the oropharyngeal, nasopharyngeal and laryngeal mask airways. Additionally the intensive care paramedic has endotracheal intubation in their scope (National Ambulance Sector Clinical Working Group, 2013). No New Zealand studies describing the type or frequency of airway adjunct use during OHCA were identified in the literature; this is a potential future research opportunity.

The 2010 Guidelines describe the correct hand position as: “the heel of one hand on the centre of the chest, which is the lower part of the sternum, with the heel of the other hand on top of the first so that the hands are overlapped and parallel” (Berg et al., 2010, p. S670). The hand placement description makes the assumption that chest compressions are being performed from-the-side and thus the transverse creases of the palmar surface of the wrist (rasceta) are parallel to the sternum. Previous studies comparing OTH and FTS chest compressions describe a similar hand placement with the exception that the rasceta of the person performing chest compressions was perpendicular to the sternum, not parallel, when compressions were performed OTH. A future research opportunity could be to investigate hand position during performance of OTH chest compressions and any association with patient musculoskeletal injury when the hand of the person performing chest compressions is positioned with the rasceta parallel or perpendicular to the patient's sternum.

Numerous studies have reported deterioration in CPR performance as a function of time, typically attributed to rescuer fatigue (Ashton, et al., 2002; McDonald, et al., 2013; Sugerman, et al., 2009). In this study there was no deterioration in CPR quality observed across the successive cycles of CPR compared to the first cycle. This observation may be due to the compliance of the participants with the 2010 Guidelines which states the person performing chest compressions should change every cycle. Alternatively the absence of the effect of rescuer fatigue may be due to the participant's performance being affected by the fact that they are participating in a study that is assessing CPR performance, or that the participant's performance may not necessarily be reflective of the paramedic population. Hence a future study opportunity could be to investigate CPR performance over time during a simulated cardiac arrest with a larger sample size. Additionally CPR quality data could be extracted from Q-CPR® capable defibrillators so that CPR performance over the duration of CPR in the clinical setting can be evaluated. The participants could be blinded to the clinical aim of the study and this would directly measure the performance on the actual population strengthening the level of evidence associated with the study. There may also be the opportunity to compare simulation and clinical performance, further informing the translation from the simulation to clinical practice environment debate.

Conclusion:

In summary there are four main findings; firstly, Q-CPR® may be used as an alternative to LSR for the measurement of CPR quality metrics during paramedic CPR training. The use of Q-CPR® during training enables the paramedics to train as they would practice in the clinical environment and has the added advantage of having a greater degree of analysis, compared to the LSR, of the CPR performance.

Secondly, the quality of CPR delivered by the paramedic was not influenced by the position from which they performed chest compressions, either from-the-side, or over-the-head. The use of the composite method, where the person at the head of the patient performs CPR over-the-head, is an acceptable alternative to the standard CPR where compressions are always performed from-the-side. Human studies are needed to confirm translation of these findings into clinical practice.

Thirdly, there was a high incidence of leaning observed across both studies. Further education is warranted to eliminate leaning. The mean difference in depth measurement between the LSR and Q-CPR® devices was observed to increase with increasing incidence of leaning. When using the Q-CPR® device, disabling the voice feedback which corrects leaning is not recommended.

Finally, paramedics performed well delivering high quality CPR consistent with the 2010 Guidelines, across the quality of CPR metrics measured in the studies presented in this thesis. In the final study comparing paramedic position, the mean depth of compression did not meet the 2010 Resuscitation Guidelines which stipulates that the depth of chest compression for an adult should be greater than 50mm. Further education to increase the depth of chest compression is warranted. The 2010 Guidelines message of ‘push hard and fast’ appears to be translated into New Zealand paramedic practice in the cohort of paramedics that participated in the studies in this thesis.

REFERENCES

2005 International Consensus on Cardiopulmonary Resuscitation and Emergency Cardiovascular Care Science with Treatment Recommendations. Part 2: Adult basic life support. (2005). *Resuscitation*, 67(2-3), 187-201. doi: 10.1016/j.resuscitation.2005.09.016

Aase, S. O., & Myklebust, H. (2002). Compression depth estimation for CPR quality assessment using DSP on accelerometer signals. IEEE transactions on bio-medical engineering, 49(3), 263-268. doi: 10.1109/10.983461

Abella, B. S., Alvarado, J. P., Myklebust, H., Edelson, D. P., Barry, A., O'Hearn, N., . . . Becker, L. B. (2005). Quality of cardiopulmonary resuscitation during in-hospital cardiac arrest. *JAMA*, 293(3), 305-310. doi: 10.1001/jama.293.3.305

Ashton, A., McCluskey, A., Gwinnutt, C. L., & Keenan, A. M. (2002). Effect of rescuer fatigue on performance of continuous external chest compressions over 3 min. *Resuscitation*, 55(2), 151-155. doi: http://dx.doi.org/10.1016/S0300-9572(02)00168-5

Bailey, E. D., Wydro, G. C., & Cone, D. C. (2000). Termination of resuscitation in the prehospital setting for adult patients suffering nontraumatic cardiac arrest. National Association of EMS Physicians Standards and Clinical Practice Committee. *Prehospital Emergency Care*:4(2), 190-195.

Berdowski, J., Berg, R. A., Tijssen, J. G., & Koster, R. W. (2010). Global incidences of out-of-hospital cardiac arrest and survival rates: Systematic review of 67 prospective studies. *Resuscitation*, 81(11), 1479-1487. doi: 10.1016/j.resuscitation.2010.08.006

Berg, R. A., Hemphill, R., Abella, B. S., Aufderheide, T. P., Cave, D. M., Hazinski, M. F., . . . Swor, R. A. (2010). Part 5: adult basic life support: 2010 American Heart Association Guidelines for Cardiopulmonary Resuscitation and Emergency Cardiovascular Care. *Circulation*, 122(18 Suppl 3), S685-705. doi: 10.1161/CIRCULATIONAHA.110.970939

Berg, R. A., Sanders, A. B., Kern, K. B., Hilwig, R. W., Heidenreich, J. W., Porter, M. E., & Ewy, G. A. (2001). Adverse hemodynamic effects of interrupting chest compressions for rescue breathing during cardiopulmonary resuscitation for ventricular fibrillation cardiac arrest. *Circulation*, 104(20), 2465-2470.

Bjorshol, C. A., Sunde, K., Myklebust, H., Assmus, J., & Soreide, E. (2011). Decay in chest compression quality due to fatigue is rare during prolonged advanced life support in a manikin model. *Scandinavian Journal of Trauma, Resuscitation and Emergency Medicine,* 19, 46. doi: 10.1186/1757-7241-19-46

Bollig, G., Steen, P. A., & Wik, L. (2007). Standard versus over-the-head cardiopulmonary resuscitation during simulated advanced life support. Prehospital Emergency Care: 11(4), 443-447. doi: 10.1080/00207450701537050

Brucke, M., Helm, M., Schwartz, A., & Lampl, L. (2007). Two rescuer resuscitation--mission impossible? A pilot study using a manikin setting. *Resuscitation*, 74(2), 317-324. doi: 10.1016/j.resuscitation.2006.12.013

Cheskes, S., Schmicker, R. H., Christenson, J., Salcido, D. D., Rea, T., Powell, J., . . . Morrison, L. (2011). Perishock pause: an independent predictor of survival from out-of-hospital shockable cardiac arrest. *Circulation*, 124(1), 58-66. doi: 10.1161/CIRCULATIONAHA.110.010736

Chi, C. H., Tsou, J. Y., & Su, F. C. (2009). Comparison of chest compression kinematics associated with over-the-head and standard cardiopulmonary resuscitation. The American Journal of Emergency Medicine, 27(9), 1112-1116. doi: 10.1016/j.ajem.2008.08.029

Christenson, J., Andrusiek, D., Everson-Stewart, S., Kudenchuk, P., Hostler, D., Powell, J., . . . Berg, R. (2009). Chest compression fraction determines survival in patients with out-of-hospital ventricular fibrillation. *Circulation*, 120(13), 1241-1247. doi: 10.1161/CIRCULATIONAHA.109.852202

Chugh, S. S., Reinier, K., Teodorescu, C., Evanado, A., Kehr, E., Al Samara, M., . . . Jui, J. (2008). Epidemiology of sudden cardiac death: clinical and research implications. *Progress in cardiovascular diseases*, 51(3), 213-228. doi: 10.1016/j.pcad.2008.06.003

Crone, P. D. (1995). Auckland Ambulance Service cardiac arrest data 1991-3. *The New Zealand Medical Journal*, 108(1004), 297-299.

Edelson, D. P., Abella, B. S., Kramer-Johansen, J., Wik, L., Myklebust, H., Barry, A. M., . . . Becker, L. B. (2006). Effects of compression depth and pre-shock pauses predict defibrillation failure during cardiac arrest. *Resuscitation*, 71(2), 137-145. doi: 10.1016/j.resuscitation.2006.04.008

Field, J. M., Hazinski, M. F., Sayre, M. R., Chameides, L., Schexnayder, S. M., Hemphill, R., . . . Vanden Hoek, T. L. (2010). Part 1: executive summary: 2010 American Heart Association Guidelines for Cardiopulmonary Resuscitation and Emergency Cardiovascular Care. *Circulation*, 122(18 Suppl 3), S640-656. doi: 10.1161/CIRCULATIONAHA.110.970889

Foo, N. P., Chang, J. H., Lin, H. J., & Guo, H. R. (2010). Rescuer fatigue and cardiopulmonary resuscitation positions: A randomized controlled crossover trial. *Resuscitation*, 81(5), 579-584. doi: 10.1016/j.resuscitation.2010.02.006

Fried, D. A., Leary, M., Smith, D. A., Sutton, R. M., Niles, D., Herzberg, D. L., . . . Abella, B. S. (2011). The prevalence of chest compression leaning during in-hospital cardiopulmonary resuscitation. *Resuscitation*, 82(8), 1019-1024. doi: 10.1016/j.resuscitation.2011.02.032

Gormley, G., Sterling, M., Menary, A., & McKeown, G. (2012). Keeping it real! Enhancing realism in standardised patient OSCE stations. The clinical teacher, 9(6), 382-386. doi: 10.1111/j.1743-498X.2012.00626.x

Grasner, J. T., & Bossaert, L. (2013). Epidemiology and management of cardiac arrest: What registries are revealing. Best practice & research. *Clinical Anaesthesiology*, 27(3), 293-306. doi: 10.1016/j.bpa.2013.07.008

Gray, R., Iyanaga, M., & Wang, H. E. (2012). Decreases in basic life support chest compression fraction after advanced life support arrival. *Resuscitation*, 83(11), e208-209. doi: 10.1016/j.resuscitation.2012.07.021

Gundersen, K., Nysaether, J., Kvaloy, J. T., Kramer-Johansen, J., & Eftestol, T. (2009). Chest compression quality variables influencing the temporal development of ROSC-predictors calculated from the ECG during VF. *Resuscitation*, 80(2), 177-182. doi: 10.1016/j.resuscitation.2008.09.011

Handley, A. J., & Handley, J. A. (2004). Performing chest compressions in a confined space. Resuscitation, 61(1), 55-61. doi: 10.1016/j.resuscitation.2003.11.012

Haque, I. U., Udassi, J. P., Udassi, S., Theriaque, D. W., Shuster, J. J., & Zaritsky, A. L. (2008). Chest compression quality and rescuer fatigue with increased compression to ventilation ratio during single rescuer pediatric CPR. Resuscitation, 79(1), 82-89. doi: 10.1016/j.resuscitation.2008.04.026

Hasegawa, T., Daikoku, R., Saito, S., & Saito, Y. (2014). Relationship between weight of rescuer and quality of chest compression during cardiopulmonary resuscitation. *Journal of Physiological Anthropology*, 33(1), 16.

Hopkins, W. G., Marshall, S. W., Batterham, A. M., & Hanin, J. (2009). Progressive statistics for studies in sports medicine and exercise science. Medicine and science in sports and exercise, 41(1), 3-13. doi: 10.1249/MSS.0b013e31818cb278

Hupfl, M., Duma, A., Uray, T., Maier, C., Fiegl, N., Bogner, N., & Nagele, P. (2005). Over-the-head cardiopulmonary resuscitation improves efficacy in basic life support performed by professional medical personnel with a single rescuer: a simulation study. *Anesthesia and Analgesia*, 101(1), 200-205. doi: 10.1213/01.ANE.0000154305.70984.6B

Jantti, H., Silfvast, T., Turpeinen, A., Kiviniemi, V., & Uusaro, A. (2009). Influence of chest compression rate guidance on the quality of cardiopulmonary resuscitation performed on manikins. *Resuscitation*, 80(4), 453-457. doi: 10.1016/j.resuscitation.2009.01.001

Koster, R. W., Sayre, M. R., Botha, M., Cave, D. M., Cudnik, M. T., Handley, A. J., . . . Travers, A. H. (2010). Part 5: Adult basic life support: 2010 International consensus on cardiopulmonary resuscitation and emergency cardiovascular care science with treatment recommendations. *Resuscitation*, 81 Suppl 1, e48-70. doi: 10.1016/j.resuscitation.2010.08.005

Kramer-Johansen, J., Edelson, D. P., Losert, H., Kohler, K., & Abella, B. S. (2007). Uniform reporting of measured quality of cardiopulmonary resuscitation (CPR). *Resuscitation*, 74(3), 406-417. doi: 10.1016/j.resuscitation.2007.01.024

Kramer-Johansen, J., Myklebust, H., Wik, L., Fellows, B., Svensson, L., Sorebo, H., & Steen, P. A. (2006). Quality of out-of-hospital cardiopulmonary resuscitation with real time automated feedback: a prospective interventional study. *Resuscitation*, 71(3), 283-292. doi: 10.1016/j.resuscitation.2006.05.011

Madden, C. (2006). Undergraduate nursing students' acquisition and retention of CPR knowledge and skills. Nurse education today, 26(3), 218-227. doi: 10.1016/j.nedt.2005.10.003

Maisch, S., Gamon, E., Ilisch, A., Goetz, A. E., & Schmidt, G. N. (2011). Comparison of the over-the-head, lateral and alternating positions during cardiopulmonary resuscitation performed by a single rescuer with a bag--valve--mask device: *EMJ*, 28(11), 974-978. doi: 10.1136/emj.2010.098251

Maisch, S., Issleib, M., Kuhls, B., Mueller, J., Horlacher, T., Goetz, A. E., & Schmidt, G. N. (2010). A Comparison Between Over-The-Head and Standard Cardiopulmonary Resuscitation Performed by Two Rescuers: A Simulation Study. *The Journal of Emergency Medicine,* 39(3), 369-376. doi: http://dx.doi.org/10.1016/j.jemermed.2009.04.055

McDonald, C. H., Heggie, J., Jones, C. M., Thorne, C. J., & Hulme, J. (2013). Rescuer fatigue under the 2010 ERC guidelines, and its effect on cardiopulmonary resuscitation (CPR) performance. *EMJ*, 30(8), 623-627. doi: 10.1136/emermed-2012-201610

Meaney, P. A., Bobrow, B. J., Mancini, M. E., Christenson, J., de Caen, A. R., Bhanji, F., . . . Leary, M. (2013). Cardiopulmonary resuscitation quality: [corrected] improving cardiac resuscitation outcomes both inside and outside the hospital: a consensus statement from the American Heart Association. *Circulation*, 128(4), 417-435. doi: 10.1161/CIR.0b013e31829d8654

Niles, D., Nysaether, J., Sutton, R., Nishisaki, A., Abella, B. S., Arbogast, K., . . . Nadkarni, V. (2009). Leaning is common during in-hospital pediatric CPR, and decreased with automated corrective feedback. *Resuscitation*, 80(5), 553-557. doi: 10.1016/j.resuscitation.2009.02.012

Niles, D., Sutton, R. M., Donoghue, A., Kalsi, M. S., Roberts, K., Boyle, L., . . . Nadkarni, V. (2009). "Rolling Refreshers": a novel approach to maintain CPR psychomotor skill competence. *Resuscitation*, 80(8), 909-912. doi: 10.1016/j.resuscitation.2009.04.021

Niles, D., Sutton, R. M., Nadkarni, V. M., Glatz, A., Zuercher, M., Maltese, M. R., . . . Berg, R. A. (2011). Prevalence and hemodynamic effects of leaning during CPR. *Resuscitation*, 82 Suppl 2, S23-26. doi: 10.1016/S0300-9572(11)70147-2

Nolan, J. P., Hazinski, M. F., Billi, J. E., Boettiger, B. W., Bossaert, L., de Caen, A. R., . . . Zideman, D. (2010). Part 1: Executive summary: 2010 International Consensus on Cardiopulmonary Resuscitation and Emergency Cardiovascular Care Science With Treatment Recommendations. *Resuscitation*, 81 Suppl 1, e1-25. doi: 10.1016/j.resuscitation.2010.08.002

Nolan, J. P., Neumar, R. W., Adrie, C., Aibiki, M., Berg, R. A., Bottiger, B. W., . . . Hoek, T. V. (2008). Post-cardiac arrest syndrome: epidemiology, pathophysiology, treatment, and prognostication. A Scientific Statement from the International Liaison Committee on Resuscitation; the American Heart Association Emergency Cardiovascular Care Committee; the Council on Cardiovascular Surgery and Anesthesia; the Council on Cardiopulmonary, Perioperative, and Critical Care; the Council on Clinical Cardiology; the Council on Stroke. *Resuscitation*, 79(3), 350-379. doi: 10.1016/j.resuscitation.2008.09.017

Oh, J., Song, Y., Kang, B., Kang, H., Lim, T., Suh, Y., & Chee, Y. (2012). The use of dual accelerometers improves measurement of chest compression depth. *Resuscitation*, 83(4), 500-504. doi: 10.1016/j.resuscitation.2011.09.028

Perkins, G. D., Kocierz, L., Smith, S. C., McCulloch, R. A., & Davies, R. P. (2009). Compression feedback devices over estimate chest compression depth when performed on a bed. *Resuscitation*, 80(1), 79-82. doi: 10.1016/j.resuscitation.2008.08.011

Perkins, G. D., Stephenson, B. T., Smith, C. M., & Gao, F. (2004). A comparison between over-the-head and standard cardiopulmonary resuscitation. *Resuscitation*, 61(2), 155-161. doi: 10.1016/j.resuscitation.2004.01.006

Robinson, S., Swain, A. H., Hoyle, S. R., & Larsen, P. D. (2010). Survival from out-of-hospital cardiac arrest in New Zealand following the 2005 resuscitation guideline changes. *Resuscitation*, 81(12), 1648-1651. doi: 10.1016/j.resuscitation.2010.07.009

Rossetti, A. O., & Koenig, M. A. (2011). Prognostication after cardiac arrest: a tale of timing, confounders, and self-fulfillment. *Neurology*, 77(14), 1324-1325. doi: 10.1212/WNL.0b013e318231533b

Sayre, M. R., Koster, R. W., Botha, M., Cave, D. M., Cudnik, M. T., Handley, A. J., . . . Travers, A. H. (2010). Part 5: Adult basic life support: 2010 International Consensus on Cardiopulmonary Resuscitation and Emergency Cardiovascular Care Science With Treatment Recommendations. *Circulation*, 122(16 Suppl 2), S298-324. doi: 10.1161/CIRCULATIONAHA.110.970996

Sayre, M. R., O'Connor, R. E., Atkins, D. L., Billi, J. E., Callaway, C. W., Shuster, M., . . . Hazinski, M. F. (2010). Part 2: evidence evaluation and management of potential or perceived conflicts of interest: 2010 American Heart Association Guidelines for Cardiopulmonary Resuscitation and Emergency Cardiovascular Care. *Circulation*, 122(18 Suppl 3), S657-664. doi: 10.1161/CIRCULATIONAHA.110.966861

Stiell, I. G., Brown, S. P., Christenson, J., Cheskes, S., Nichol, G., Powell, J., . . . Callaway, C. W. (2012). What is the role of chest compression depth during out-of-hospital cardiac arrest resuscitation? *Critical Care Medicine*, 40(4), 1192-1198. doi: 10.1097/CCM.0b013e31823bc8bb

Sugerman, N. T., Edelson, D. P., Leary, M., Weidman, E. K., Herzberg, D. L., Vanden Hoek, T. L., . . . Abella, B. S. (2009). Rescuer fatigue during actual in-hospital cardiopulmonary resuscitation with audiovisual feedback: A prospective multicenter study. *Resuscitation*, 80(9), 981-984. doi: http://dx.doi.org/10.1016/j.resuscitation.2009.06.002

Tomkins, W. G. O., Swain, A. H., Bailey, M., & Larsen, P. D. (2013). Beyond the pre-shock pause: the effect of prehospital defibrillation mode on CPR interruptions and return of spontaneous circulation. *Resuscitation*, 84(5), 575-579. doi: http://dx.doi.org/10.1016/j.resuscitation.2012.12.018

Travers, A. H., Rea, T. D., Bobrow, B. J., Edelson, D. P., Berg, R. A., Sayre, M. R., . . . Swor, R. A. (2010). Part 4: CPR overview: 2010 American Heart Association Guidelines for Cardiopulmonary Resuscitation and Emergency Cardiovascular Care. *Circulation*, 122(18 Suppl 3), S676-684. doi: 10.1161/CIRCULATIONAHA.110.970913

Vadeboncoeur, T., Stolz, U., Panchal, A., Silver, A., Venuti, M., Tobin, J., . . . Bobrow, B. (2014). Chest compression depth and survival in out-of-hospital cardiac arrest. *Resuscitation*, 85(2), 182-188. doi: 10.1016/j.resuscitation.2013.10.002

Vaillancourt, C., Everson-Stewart, S., Christenson, J., Andrusiek, D., Powell, J., Nichol, G., . . . Stiell, I. G. (2011). The impact of increased chest compression fraction on return of spontaneous circulation for out-of-hospital cardiac arrest patients not in ventricular fibrillation. *Resuscitation*, 82(12), 1501-1507. doi: 10.1016/j.resuscitation.2011.07.011

Vaillancourt, C., Midzic, I., Taljaard, M., & Chisamore, B. (2011). Performer fatigue and CPR quality comparing 30:2 to 15:2 compression to ventilation ratios in older bystanders: A randomized crossover trial. *Resuscitation*, 82(1), 51-56. doi: 10.1016/j.resuscitation.2010.09.003

Vivier, S. A. (2010). The quest for high-quality CPR. A team-based approach & feedback help the Henderson (Nev.) Fire Department improve CPR effectiveness. JEMS, 35(9), suppl 3-5.

Wang, H. E., Simeone, S. J., Weaver, M. D., & Callaway, C. W. (2009). Interruptions in Cardiopulmonary Resuscitation From Paramedic Endotracheal Intubation. *Annals of Emergency Medicine*, 54(5), 645-652.e641. doi: http://dx.doi.org/10.1016/j.annemergmed.2009.05.024

Wang, H. E., & Yealy, D. M. (2013). Managing the airway during cardiac arrest. *JAMA*, 309(3), 285-286. doi: 10.1001/jama.2012.216998

Wik, L., Kramer-Johansen, J., Myklebust, H., Sorebo, H., Svensson, L., Fellows, B., & Steen, P. A. (2005). Quality of cardiopulmonary resuscitation during out-of-hospital cardiac arrest. *JAMA*, 293(3), 299-304. doi: 10.1001/jama.293.3.299

Yeung, J., Meeks, R., Edelson, D., Gao, F., Soar, J., & Perkins, G. D. (2009). The use of CPR feedback/prompt devices during training and CPR performance: A systematic review. *Resuscitation*, 80(7), 743-751. doi: 10.1016/j.resuscitation.2009.04.012

Zuercher, M., Hilwig, R. W., Ranger-Moore, J., Nysaether, J., Nadkarni, V. M., Berg, M. D., . . . Berg, R. A. (2010). Leaning during chest compressions impairs cardiac output and left ventricular myocardial blood flow in piglet cardiac arrest. *Critical Care Medicine*, 38(4), 1141-1146. doi: 10.1097/CCM.0b013e3181ce1fe2

Appendix 1 Auckland University Ethics Committee Approval

AUT UNIVERSITY
TE WĀNANGA ARONUI O TAMAKI MAKAU RAU

A U T E C
S E C R E T A R I A T

5 February 2013

Chris Whatman
Health and Environmental Sciences

Dear Chris

Re: **13/10 The affect of paramedic position on external chest compression quality: A simulation study.**

Thank you for submitting your application for ethical review. I am pleased to confirm that the Auckland University of Technology Ethics Committee (AUTEC) has approved your ethics application for three years until 4 February 2016.

AUTEC recommends that the word 'affect' in the title should be altered to 'effect'.

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

- A brief annual progress report using form EA2, which is available online through http://www.aut.ac.nz/researchethics. When necessary this form may also be used to request an extension of the approval at least one month prior to its expiry on 4 February 2016;
- A brief report on the status of the project using form EA3, which is available online through http://www.aut.ac.nz/researchethics. This report is to be submitted either when the approval expires on 4 February 2016 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. If your research is undertaken within a jurisdiction outside New Zealand, you will need to make the arrangements necessary to meet the legal and ethical requirements that apply within their.

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

All the very best with your research,

Dr Rosemary Godbold
Executive Secretary
Auckland University of Technology Ethics Committee

Cc: Paul Davey paul.davey@aut.ac.nz

Appendix 1 St John Locality Approval

St John
first to care

18 April 2013

Paul Davey
90 Akoranga Dr
Northcote
Room AN103B
Private Bag 92006
Auckland 1142

Study title: The effect of paramedic position on external chest compression quality: A simulation study

St John reference: 0009

Dear Mr Davey

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

1. Project reports must be submitted to St John on the following dates:

- 1-August 2013 Interim Progress Report #1
- 12-December 2013 Final Report
- The final report should be submitted at the completion of the study. This should be returned to St John within four weeks of the project completion. The date stated above is the anticipated final report date for this project. If this is to be extended please state this in the Interim Progress Report #1 and our records will be amended. The final report should provide a synopsis outlining the results and conclusions from the study.
- Please use the *OMF 4.9.8 Research Status Report* for report submissions.

2. All researchers involved in the study are required to complete a copy of the *OMF 4.9.7 Research memorandum of understanding*.

Yours sincerely

Bridget Dicker

Dr Bridget Dicker, PhD
Clinical Research Coordinator

Copy Dr Chris Whatman

Attachments OMF 4.9.8 Research Status Report
OMF 4.9.7 Research Memorandum of Understanding

Bridget Dicker | Clinical Research Coordinator | St John
T 09 5260527 ext 8771 | M 027 705 2617 | E bridget.dicker@stjohn.org.nz
8 Harrison Road I Mt Wellington | Auckland I New Zealand
www.stjohn.org.nz

Appendix 2 Paramedics Australasia International Research Conference Canberra October 17-19, 2013

- Award for Best Scientific Poster
- Abstract published in the Australasian Journal of Paramedicine

Davey, P., Whatman, C. & Dicker B. (2014). The effect of paramedic position on external chest compression quality. A simulation study. *Australasian Journal of Paramedicine, 11*(1), 16. Retrieved from http://ro.ecu.edu.au/jephc/vol11/iss1/1

Abstract: The effect of paramedic position on external chest compression quality. A simulation study.

Paul Davey[1], Chris Whatman[1], Bridget Dicker[1,2]
[1] Auckland University of Technology, Auckland, New Zealand
[2] St John, National Office, New Zealand

Introduction
During cardiopulmonary resuscitation (CPR) standard external chest compression (ECC) is performed from the side. Paramedics commonly perform external chest compressions from the side and/or over-the-head; with over-the-head being utilised by one paramedic to facilitate other interventions such as establishing intravenous access and administering pharmaceutical agents by the second paramedic.

This study seeks to validate the use of over-the-head ECC by a crew of two paramedics subsequent to the introduction of the 2010 resuscitation guidelines. Analysis of CPR quality, including ECC rate, depth, hand position, rescuer leaning-hand release and chest compression fraction was undertaken in a simulated environment

Methods
The methodology is positivist as a quantitative study. In a standardised simulated scenario each participant (n=30) performed chest compressions in two positions, alternating over-the-head and from-the-side, subsequently the CPR quality indicators will be compared for each participant to see if there is a difference in CR quality performed by that participant I the two positions. In addition participant weight, height , arm span and CPR variables are evaluated. The study design is a randomised cross over trial, with the position that the participant starts compressions being randomised. Participants will work in pairs and will be randomly allocated to the role of rescuer 1 or rescuer 2.

Results
Data currently being collected (all data will be collected by June 12th 2013)

Conclusions
To be drawn subsequent to data collection and analysis

The effect of paramedic position on external chest compression quality: A simulation study

[1]Paul Davey PGDipHSc, PGCertHEAL [1]Chris Whatman PhD [1,2]Bridget Dicker PhD

1. AUT University, Auckland, New Zealand. 2. St John, Auckland, New Zealand.

St John

first to care

Introduction

Chest compression technique performed with the rescuer positioned over the head (OTH) was introduced as a solution to performing CPR in confined spaces and for a single rescuer ventilating with a manual bag ventilator. No studies have evaluated OTH compressions for extended periods[1-4] or subsequent to the introduction of the 2010 Resuscitation Guidelines, which have a greater emphasis on quality of chest compressions.[5]

Aim: To evaluate the effect of paramedic position on external chest compression quality.

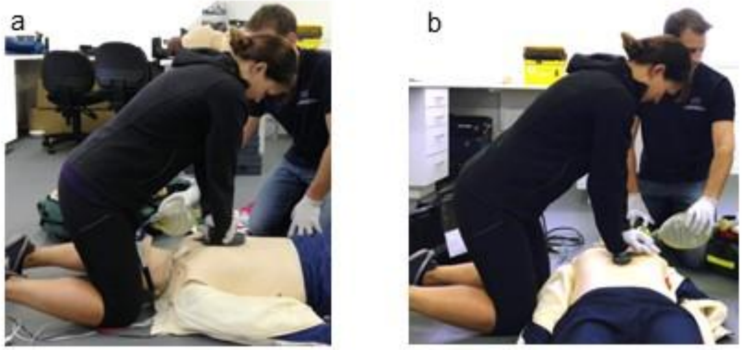


Figure 1. Chest compression performed over the head of the manikin (a) or from the side (b).

Methods

- 30 paramedics from St John were paired and randomised so that one performed chest compressions positioned the OTH and the other from the side (FTS) (Figure 1).
- The pair performed CPR, changing chest compressor each cycle, stopping after ten cycles.
- After a 10min rest period paramedics changed positions and then repeated CPR for a further ten cycles.
- Chest compression variables were measured using Q-CPR with feedback disabled.
- Ethical approval was gained (AUTEC 13/10; St John Research Committee Reg: 009).

References

1. Bollig, G., Steen, P. A., & Wik, L. (2007). Standard versus over-the-head cardiopulmonary resuscitation during simulated advanced life support. Prehospital Emergency Care, 11(4), 443-447.
2. Handley, A. J., & Handley, J. A. (2004). Performing chest compressions in a confined space. Resuscitation, 61(1), 55-61.
3. Maisch, S., Issleib, M., Kuhls, B., Mueller, J., Horlacher, T., Goetz, A. E., & Schmidt, G. N. (2010). A Comparison Between Over-The-Head and Standard Cardiopulmonary Resuscitation Performed by Two Rescuers: A Simulation Study. The Journal of Emergency Medicine, 39(3), 369-376.
4. Perkins, G. D., Stephenson, B. T., Smith, C. M., & Gao, F. (2004). A comparison between over-the-head and standard cardiopulmonary resuscitation. Resuscitation, 61(2), 155-161.
5. Travers, A. H., Rea, T. D., Bobrow, B. J., et al. (2010). Part 4: CPR overview: 2010 American Heart Association Guidelines for Cardiopulmonary Resuscitation and Emergency Cardiovascular Care. Circulation, 122(18 Suppl 3), S676-684.

Findings

- No significant differences between OTH or FTS for any variables related to chest compression quality (Figure 2).
- The 'No Flow' period per cycle, in which no compressions are performed, was 3.4 ±1.1s (mean ± SD) for both positions ($p=0.817$).
- CPR cycle length, average rate of compressions, duty cycle, and 'No Flow' period for both positions meet the 2010 Resuscitation Guidelines.
- Average compression depth OTH satisfies the Q-CPR compression depth range of 38 – 50 mm, however falls short of >50 mm stipulated in the 2010 Resuscitation Guidelines.
- For both positions the number of compressions per cycle with leaning (inadequate hand release) represents ~18% of all compressions delivered.

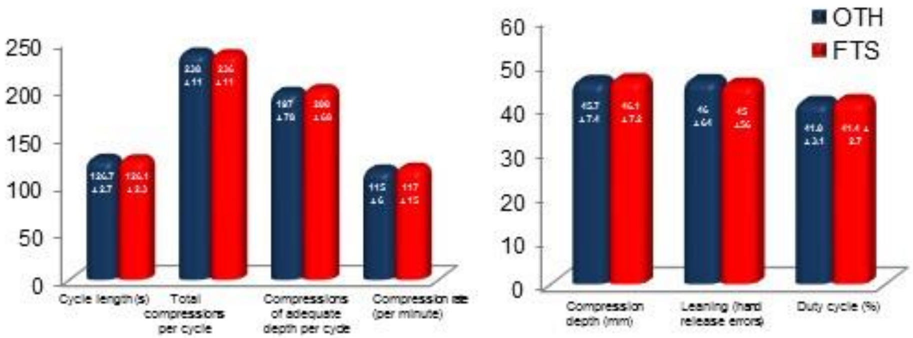


Figure 2. Comparison of outcome variables (mean ± SD) for chest compressions performed over the head (OTH) and from the side (FTS).

Conclusions

- Paramedic position, over the head or from the side, does not effect external chest compression quality when performed on a manikin.
- Further education in regards to depth of compression and leaning is warranted.

Take home message:

Chest compression when performed OTH or FTS produced no significant difference in:

- length of CPR cycle
- compression rate
- compression depth
- leaning
- period of no flow time
- duty cycle

Appendix 3 New Zealand Resuscitation Conference: Poster presentation

Title The frequency of leaning and its association with depth of compression measurement during simulated CPR.

Paul Davey[1], Dr Bridget Dicker[1,2], Dr Chris Whatman[3]

[1] Auckland University of Technology, Faculty of Health and Environmental Science.
[2] St John
[3] Auckland University of Technology, Senior Lecturer, Sport Performance Research Institute New Zealand, Auckland, New Zealand

Introduction: There has been an increased emphasis on quality and measurement of chest compression in both clinical and simulated settings. Leaning is considered a key variable. The aims of this study were: to identify the frequency of leaning by paramedics performing CPR in a simulated setting, and to determine if a relationship exists between the frequency of leaning and the depth of compression as measured by the Q-CPR® device.

Methods: Paramedics (n=15) each performed two sessions of chest compressions on a Resusci Anne® simulator of two minute duration separated by a two minute rest period... The quality of chest compressions in each two minute session was concurrently measured using both Q-CPR® incorporated into the Heartstart MRx™ defibrillator and the Laerdal Skill Reporter system. The audio-visual feedback system of Q-CPR® was disabled.

Results: Of the 30 simulated CPR sessions 21 exhibited some degree of leaning. In 37% of the CPR sessions a frequency of leaning was observed in less than 1% of the chest compressions. However in 20% of the sessions leaning was observed in greater than 20% of the chest compressions. Where there was leaning Q-CPR® reported a shorter depth of chest compression compared to the Laerdal Skill Reporter system. There was a positive correlation (R^2=0.81) between leaning and mean difference of compression depth measured between the two devices.

Conclusion: In 20% of the sessions leaning was observed in greater than 20% of the compressions. When using the Q-CPR® device the audio feedback function that advises of leaning should not be disabled.

The frequency of leaning and its association with depth of compression measurement during simulated CPR.

Paul Davey PGDipHSc, PGDipHEALSc
[1,2]Bridget Dicker PhD
Chris Whatman PhD

1. Auckland University of Technology, New Zealand. 2. St John, Auckland, New Zealand.

St John
first to care

Introduction

There has been an increased emphasis on quality and measurement of chest compression in both clinical and simulated settings[1]. Leaning is considered a quality metric that should be minimised during chest compressions[1]. In animal studies leaning has been shown to reduce venous return and cardiac output subsequently reducing coronary and cerebral perfusion[2]. Leaning occurs when the person performing the chest compressions exerts residual pressure on the chest at the end of the compression which does not allow complete chest wall recoil[3] and is a common observation during chest compressions[4-6].

Aim: To identify the frequency of leaning by paramedics performing CPR in a simulated setting, and to determine if a relationship exists between the frequency of leaning and the depth of compression as measured by the Q-CPR® device

Methods

- St John paramedics (n=15) were randomised to perform chest compressions for two minutes positioned either over-the-head (OTH), or from-the-side (FTS) of the manikin.
- After a 2min rest period paramedics performed CPR for a further two minutes in the other position.
- Chest compression variables were measured concurrently using Laerdal Skill Reporter (LSR) and Q-CPR® with feedback disabled.

Findings

- Percentage of chest compressions exhibiting leaning was variable between participants (Figure 1).
- Leaning was common, 70% of participants exhibited some degree of leaning, 16.8% of all compressions performed exhibited leaning

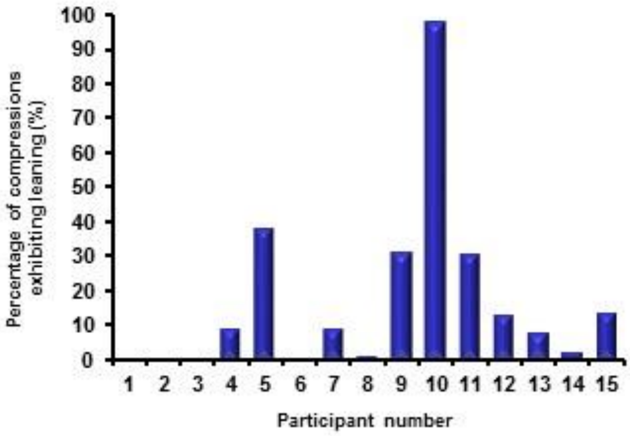


Figure 1. Percentage of chest compressions exhibiting leaning for each participant (n=15)

Findings continued

- No significant difference in the depth of compression (mean difference -0.3 (95%CI: -1.76 – 1.16), p=0.68) or leaning (mean difference -12.5 (95%CI: -25.27 – 0.34), p=0.06) between chest compressions performed OTH or FTS
- Where there was leaning Q-CPR® reported a shorter depth of chest compression compared to the Laerdal Skill Reporter system.
- There was a positive correlation (R^2=0.81) between the percentage of compression exhibiting leaning and mean difference of compression depth measured between LSR and Q-CPR® (Figure 2).

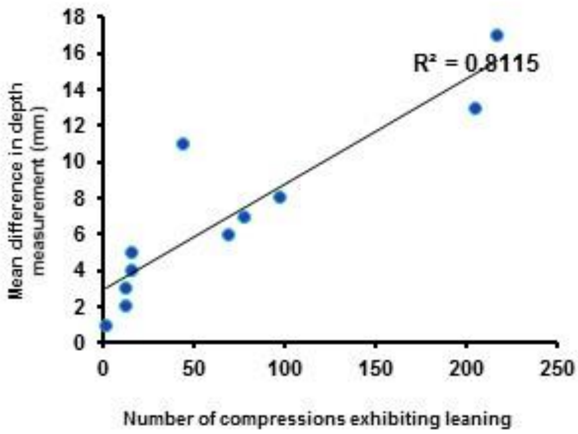


Figure 2. The association between mean difference in measurement of depth (mm) when chest compression depth is measured by the Laerdal skill report and the Q-CPR® devices.

Conclusions

- Leaning is common, in 20 % of the CPR sessions more than 20% of all compressions exhibited leaning .
- As the incidence of leaning increases the mean difference in compression depth measured between LSR and Q-CPR® devices increases

Take home message:

Leaning is common. The use of a device, such as Q-CPR®, that identifies leaning is recommended. When using Q-CPR®, disabling audio feedback, which corrects leaning, is not recommended.

References

1. Travers, A. H., Rea, T. D., Bobrow, B. J., et al. (2010). Part 4: CPR overview: 2010 American Heart Association Guidelines for Cardiopulmonary Resuscitation and Emergency Cardiovascular Care. Circulation, 122(18 Suppl 3), S676-684.
2. Zuercher, M., Hilwig, R. W., Ranger-Moore, J., ... Berg, R. A. (2010). Leaning during chest compressions impairs cardiac output and left ventricular myocardial blood flow in piglet cardiac arrest. Critical Care Medicine, 38(4), 1141-1146. doi: 10.1097/CCM.0b013e3181ce1fe2
3. Meaney, P. A., Bobrow, B. J., Mancini, M. E., ... Leary, M. (2013). Cardiopulmonary resuscitation quality: Improving cardiac resuscitation outcomes both inside and outside the hospital: a consensus statement from the American Heart Association. Circulation, 128(4), 417-435. doi: 10.1161/CIR.0b013e31829d8654
4. Fried, D. A., Leary, M., Smith, D. A., ... Abella, B. S. (2011). The prevalence of chest compression leaning during in-hospital cardiopulmonary resuscitation. Resuscitation, 82(8), 1019-1024. doi: 10.1016/j.resuscitation.2011.02.032
5. Niles, D., Sutton, R., Nadkarni, V., ... Berg, R. A. (2011). Prevalence and hemodynamic effects of leaning during CPR. Resuscitation, 82 Suppl 2, S23-26. doi: 10.1016/S0300-9572(11)70147-2
6. Niles, D., Nysaether, J., Sutton, R., ... Nadkarni, V. (2009). Leaning is common during in-hospital pediatric CPR, and decreased with automated corrective feedback. Resuscitation, 80(5), 553-557. doi: 10.1016/j.resuscitation.2009.02.012

Appendix 4 New Zealand Resuscitation Conference: Poster presentation

Title Comparison of external chest compressions measured using Laerdal Skill Reporter and Q-CPR: A manikin study.

Paul Davey[1], Dr Bridget Dicker[1,2], Dr Chris Whatman[3]

[1] Auckland University of Technology, Faculty of Health and Environmental Science.
[2] St John
[3] Auckland University of Technology, Senior Lecturer, Sport Performance Research Institute New Zealand, Auckland, New Zealand

Introduction: There has been an increased emphasis on the quality of chest compressions as a part of the cardiopulmonary resuscitation (CPR) care bundle over recent times. During CPR training chest compression quality parameters can be measured directly from sensors within a manikin or from independent devices that use accelerometer based technology.

The aim of this study was to compare external chest compression data from the manikin-based Laerdal Skill Reporter (LSR) and the puck-based Q-CPR® technology during CPR on a Resusci Anne® simulator manikin.

Methods: Paramedics (n=15) each performed two sessions of two minutes of chest compressions, with a two minute rest period in between sessions. Both over-the-head (OTH) and from-the-side positions (FTS) were used. The quality of chest compressions were concurrently measured using both Q-CPR® and the Laerdal Skill Reporter systems with audio-visual feedback disabled.

Results: There was no significant difference in the measurement of the number of chest compressions performed in two minutes, the compression rate, total number of compressions of adequate depth or the number of compressions exhibiting leaning between the LSR and Q-CPR® devices. There was a significant difference in compression depth ($p<0.0001$) and duty cycle ($p<0.0001$).

Conclusion: There was no significant difference in the majority of chest compression quality metrics measured between the LSR and the Q-CPR devices. However, there were significant differences in the measurement of duty cycle and also the depth of compressions between the two devices. These differences were observed to increase with an increasing incidence of leaning.

Comparison of external chest compressions measured using Laerdal Skill Reporter and Q-CPR: A manikin study

Paul Davey PGDipHSc, PGDipHEALSc

[1,2]Bridget Dicker PhD

Chris Whatman PhD

1. Auckland University of Technology, New Zealand. 2. St John, Auckland, New Zealand.

Introduction

There has been an increased emphasis on the quality of chest compressions as a part of the cardiopulmonary resuscitation (CPR) care bundle over recent times[1,2]. The ability to measure CPR quality and provide feedback has been shown to improve both performance and retention of CPR skills[3]. During CPR training chest compression quality parameters can be measured directly from sensors within a manikin or from independent devices that use accelerometer based technology. The use of Q-CPR™, as an example of accelerometer based technology, has been shown to improve CPR quality during training and out-of-hospital cardiac arrest[4,5].

Aim: To compare chest compression data from the manikin based Laerdal Skill Reporter (LSR) and puck based Q-CPR® technology during CPR on a Resusci Anne® simulator manikin.

Methods

- St John paramedics (n=15) were randomised to perform chest compressions for two minutes positioned either over-the-head (OTH), or from-the-side (FTS) of the manikin.
- After a two minute rest period paramedics performed CPR for a further two minutes in the other position.
- Chest compression variables were measured concurrently using Laerdal Skill Reporter (LSR) and Q-CPR® with feedback disabled, Figure 1.
- Ethical approval was gained (AUTEC 13/10; St John Reg: 009).

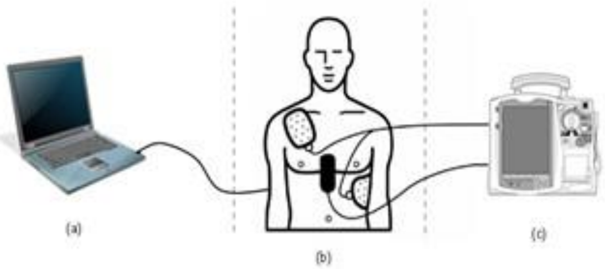


Figure 1. The experimental setup (a) the Laerdal Skill Reporter software (b) Resusci Anne manikin with central Q-CPR® puck (c) The MRx defibrillator

Findings

- No significant differences between OTH or FTS for all variables related to chest compression quality.
- There was no significant difference in the measurement of the compression rate, total number of compressions of adequate depth or the number of compressions exhibiting leaning between the LSR and Q-CPR® devices.
- There was a significant difference in the measurement of compression depth ($p<0.0001$) and duty cycle ($p<0.0001$) between the LSR and Q-CPR® devices.

Findings continued

- There was a significant difference in the measurement of the number of chest compressions performed OTH in two minutes between the LSR and Q-CPR® devices, which is not likely to be clinically significant.
- Q-CPR® reported a shorter depth of chest compression compared to LSR when chest compressions exhibited leaning.

Table 1. Chest compressions performed from the side measured using LSR and Q-CPR® devices.

	LSR mean (±SD)	Q-CPR mean (±SD)	Mean difference (95% CI)	*p* value
Number of compressions in 2 minute episode	223.9 (±23.0)	223.7 (±23.5)	0.20 (-0.36-0.76)	0.46
Compression rate (compressions per minute)	111.8 (±11.5)	111.7 (±11.6)	0.10 (-0.06-0.26)	0.20
Total compressions of adequate depth	202.3 (±58.6)	205.7 (±58.5)	-3.4 (-7.5-0.60)	0.09
Average compression depth (mm)	56.1 (±5.2)	51.9 (±5.6)	4.2 (2.18-6.35)	0.001*
Compressions with leaning	49.1 (±90.4)	31.7 (±51.9)	17.4 (-22.82-57.62)	0.37
Duty cycle (%)	44.9 (±4.6)	39.6 (±5.6)	5.3 (3.63-6.91)	<0.0001*

LSR = Laerdal Skill Reporter, Q-CPR = Quality CPR puck system *p<0.05 significant

Table 2. Chest compressions performed over the head measured using LSR and Q-CPR® devices.

	LSR mean (±SD)	Q-CPR mean (±SD)	Mean difference (95% CI)	*p* value
Number of compressions in 2 minutes	227.7 (±23.5)	227.1 (±23.4)	0.60 (0.09-1.10)	0.02*
Compression rate	113.5 (±11.8)	113.1 (±11.2)	0.33 (-0.08-0.68)	0.06
Total compressions of adequate depth	214.7 (±29.7)	213.5 (±59.3)	1.2 (-30.63-33.17)	0.93
Compression depth (mm)	57.3 (±4.7)	51.3 (±6.3)	5.9 (3.67-8.20)	<0.0001*
Compressions with leaning	74.1 (±97.8)	43.7 (±68.6)	30.33 (-27.84-88.50)	0.28
Duty cycle	44.5 (±4.1)	40.0 (±4.4)	4.5 (2.95-5.99)	<0.0001*

LSR = Laerdal Skill Reporter, Q-CPR = Quality CPR puck system *p<0.05 significant

Conclusions

- There was no significant difference in the majority of chest compression quality metrics measured between the LSR and the Q-CPR® devices
- Significant differences in the measurement of compression depth was observed between devices. The difference was observed to increase with an increasing incidence of leaning.
- Paramedic position, OTH or FTS, does not effect external chest compression quality when performed on a manikin.

Take home message:

Q-CPR® is an acceptable alternative to LSR for assessing CPR quality metrics during simulation. Caution should be exercised when interpreting compression depth in the presence of leaning.

References

1. [illegible]
2. [illegible]
3. [illegible]
4. [illegible]
5. [illegible]

Appendix 5 New Zealand Resuscitation Conference: Oral presentation

Title Does the position of the paramedic performing chest compressions during a simulated cardiac arrest influence compliance with the 2010 guidelines?

Paul Davey[1], Dr Bridget Dicker[1,2], Dr Chris Whatman[3]

[1] Auckland University of Technology, Faculty of Health and Environmental Science.
[2] St John
[3] Auckland University of Technology, Senior Lecturer, Sport Performance Research Institute New Zealand, Auckland, New Zealand

Introduction: Paramedics perform chest compressions positioned either over-the-head (OTH) or from-the-side (FTS). The OTH position permits CPR in confined spaces. No studies have evaluated OTH compressions for extended periods or since the 2010 Resuscitation Guidelines were introduced, which emphasized quality of chest compressions.

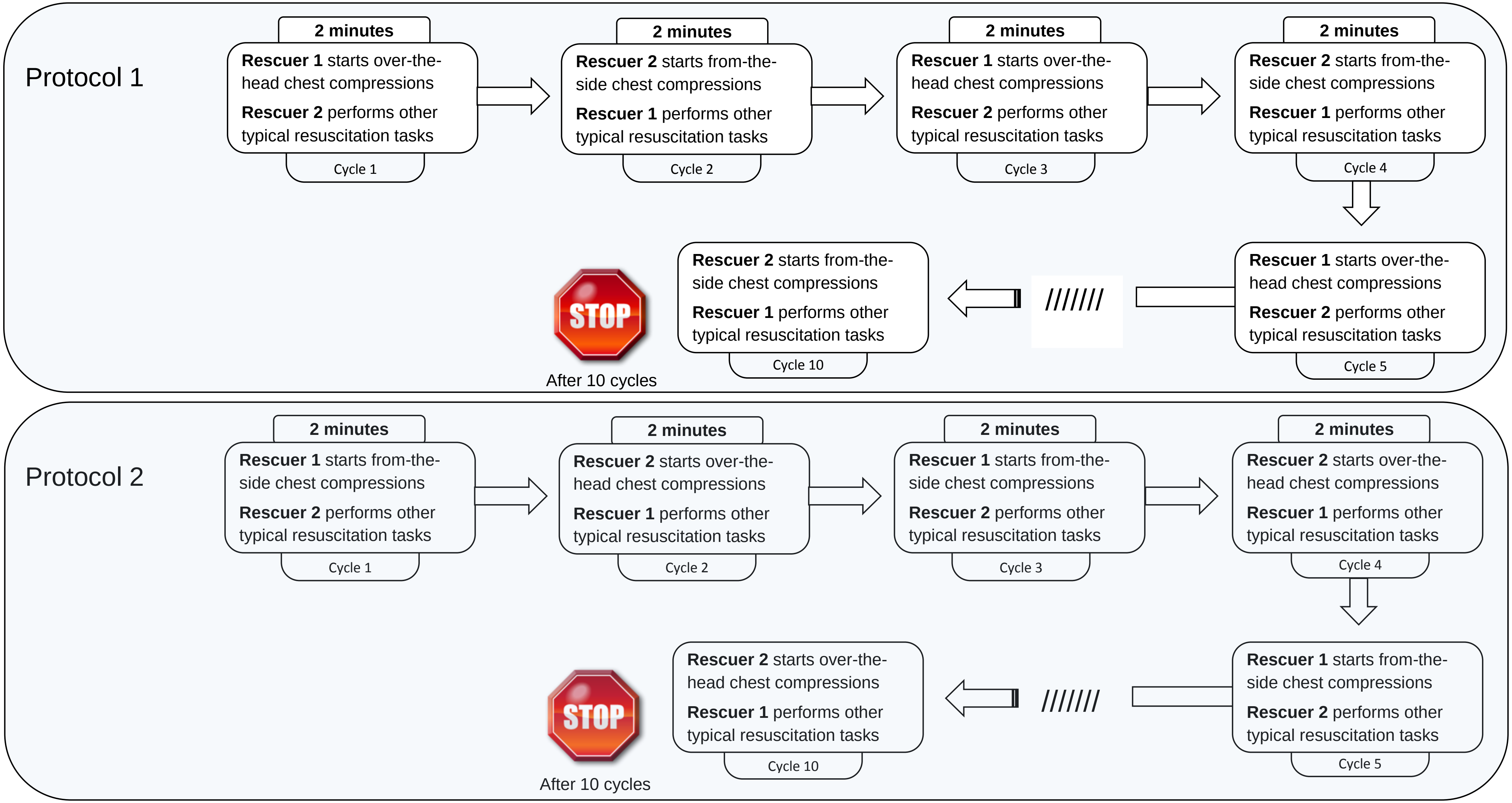
The aim of this study was to determine if paramedic position (OTH or FTS) during chest compressions influences compliance with the 2010 Guidelines.

Methods: A standardised cardiac arrest simulation using the Resusci Anne® manikin was used. Paramedics (n=30) were paired and randomised so that one performed OTH compressions and the other FTS for the duration of the simulation. The paramedic performing chest compressions alternated every cycle, stopping after a total of ten cycles. After a ten minute rest period the paramedics crossed over positions and repeated the simulation. The quality of CPR was measured using Q-CPR® with audio-visual feedback disabled.

Results: There were no significant differences between OTH and FTS for all quality variables measured. The cycle length, average compression rate, duty cycle, no flow period and ventilation rate all met the 2010 Guidelines. The incidence of leaning and compression depth did not met the 2010 Guidelines. Leaning occurred in OTH 19.3%, FTS 19.0% (p= 0.916) of all compressions, and the mean depth of compression (OTH 45.7±7.5mm, FTS 46.1±7.2mm, p=0.454) was less than the >50mm recommended.

Conclusion: The position of the paramedic performing chest compressions does not influence compliance with the 2010 Guidelines. Further education in regards to depth of compression and leaning is warranted.

Appendix 6 Study Protocol (Chapter 4) – over-the-head versus from-the-side CPR. The participants completed either Protocol 1 or 2 and then crossed over to the other protocol after a 15 minute break.



Other resuscitation tasks include:

- Analysing ECG rhythm
- Using Defibrillator
- Calling for help
- Gaining IV access
- Drug up and administer drugs
- Ventilating using a manual bag ventilator
- Setting up bags of fluid
- Connecting oxygen

Participant Information Sheet

Date Information Sheet Produced: 23rd November 2012

Project Title: Over-the-head or from-the-side – does the position of the paramedic performing external chest compression influence the quality of cardiopulmonary resuscitation? A simulation study.

An Invitation

We are Paul Davey and Chris Whatman and we are conducting research exploring if the position of the paramedic performing chest compressions; either over-the-head or from-the-side, influences the quality of CPR performed. We are using the term paramedic globally to reflect the two paramedic practising levels in New Zealand; Intermediate Life Support and Intensive Care Paramedic. We would like to invite you to participate in this research project that will utilise a simulated cardiac arrest scenario. Participation in this research project is voluntary and you may withdraw at any time

What is the purpose of this research?

Paramedics commonly perform external chest compressions from the side and/or from over-the-head; with over-the-head being utilised by one paramedic to facilitate other interventions such as establishing intravenous access and administering pharmaceutical agents by the second paramedic.

This study seeks to validate the use of over-the-head ECC by a crew of two paramedics subsequent to the introduction of the 2010 resuscitation guidelines. Analysis of CPR quality, including ECC rate, depth, hand position, rescuer lean-hand release and chest compression fraction, will be undertaken in a simulated environment.

How was I identified and why am I being invited to participate in this research?

This study is open to anyone who is employed as a practising paramedic. Students enrolled in the AUT BHSc in Paramedicine degree who are already working as paramedics are welcome to participate in this study, however students not working as paramedics are not eligible to participate. Posters advertising this study have been strategically placed in locations that urban based working paramedics will have access to.

What will happen in this research?

You will be paired with another participant and after a briefing will engage in a cardiac arrest simulation, following the 2010 Resuscitation Guidelines, that will last approximately 20 minutes. The person performing compression will change every two minutes. You will be randomly assigned to either rescuer 1 or rescuer 2. Rescuer 1 will start CPR using over-the-head compressions and will continue with this position for the duration of the scenario. The second rescuer, when required to perform compression with do so from-the-side. At the end of the simulation, after a short rest, the simulation is repeated for a further 20 minutes with rescuer 1 now starting compressions from-the-side. Rescuer 2 will then perform compressions from over-the-head position.

There will be a briefing before the simulation starts. During the briefing the protocol will be fully explained, demographic data, such as qualification, length of time as a paramedic, height, arm length, weight and ethical dilemmas faced in resuscitation will be asked. The consent form will also be signed and a copy made available for you at this time.

What are the discomforts and risks?

The simulation requires the use of a real defibrillator, the risk of electrical shock is very low. There has been no adverse event noted with the last 5000 uses of the defibrillator during simulation at AUT. It is possible that some participants may feel a range of emotions when considering the scenario. If this is the case and you would like to talk to someone about your feelings, then participants can contact AUT's Health, Counselling and Wellbeing Centre (http://www.aut.ac.nz/being-a-student/current-undergraduates/your-health-and-wellbeing /health,-counselling-and-wellbeing-centres). Participants can access this service by telephoning AUT city campus 09 921 9992 or North Shore campus 09 921 9998 indicating to staff that they are a research participant. In addition all working paramedics have access to free counselling services as a part of their employment conditions. These confidential services are provided to the paramedic at no cost and are accessed by phoning 0800 327 669.

How will these discomforts and risks be alleviated?

Your performance results will be kept confidential and also results will be de-identified. You can choose to withdraw from the study at any time. All medical equipment will be calibrated and will have a current electrical compliance certificate.

What are the benefits?

Paramedics are concerned with survivability from community cardiac arrest. This study aims to validate the use of over-the-head compressions as a technique for performing chest compressions. Your participation is valuable as the influence of the position of the paramedic performing compressions on CPR quality has not been extensively researched within the New Zealand health care environment and so this research has the potential to inform paramedic practice.

How will my privacy be protected?

As a participant your individual performance of will remain confidential. The data will be de-identified and will be securely stored on an external hard drive that will be locked in a cabinet for a maximum of six years and during this time may be used for comparative research with other cohorts of paramedics and other health professionals.

What are the costs of participating in this research?

The study will be conducted in the Skills Lab (Taiwhanga pukenga) AN101 at the North Shore Campus of the Auckland University of Technology. There is cost associated with you travelling to AUT and parking in Carpark 7 ($1 per hour). A parking ticket can be obtained from the Paramedicine and Emergency Management reception, AN block, which will enable free car parking in car park 7. The time cost for participating in this study is expected to be approximately one hour. At completion of your participation you will receive a koha of a $20.00 petrol voucher.

What opportunity do I have to consider this invitation?

Paul is happy for you to contact him with any questions you may have about the research. If you have any questions or would like to participate, please email or phone Paul paul.davey@aut.ac.nz or 09 9219999 extension 7155. The participation period is between the 15th of January and the end of February 2013.

How do I agree to participate in this research?

If you wish to participate in this research please email the primary researcher Paul - paul.davey@aut.ac.nz who will contact you to discuss the research in more detail and give you opportunity to ask questions. If you are happy to proceed Paul will arrange a time for you meet, sign the consent form and to participate in the study. You may withdraw consent and decide not to participate at any time without prejudice.

Will I receive feedback on the results of this research?

If you would like feedback on the results of this research you can check the checkbox on the consent form and we will send you a summary of the results. Note that the results will be de-identified to ensure anonymity of individual results. In addition, we will present findings to the School of Paramedicine, St John and Wellington Free Ambulance.

What do I do if I have concerns about this research?

Any concerns regarding the nature of this project should be notified in the first instance to the Project Supervisor, Dr Chris Whatman, chris.whatman@aut.ac.nz, 09 921 9999 ext 7037.

Concerns regarding the conduct of the research should be notified to the Executive Secretary, AUTEC, Dr Rosemary Godbold, rosemary.godbold@aut.ac.nz , 921 9999 ext 6902.

Whom do I contact for further information about this research?

RESEARCHER CONTACT DETAILS:

Paul Davey: please email Paul – paul.davey@aut.ac.nz, or phone 09 921 9999 ext 7155.

PROJECT SUPERVISOR CONTACT DETAILS:

Dr Chris Whatman, chris.whatman@aut.ac.nz, 09 921 9999 ext 7037

Approved by the Auckland University of Technology Ethics Committee on 5 February AUTEC Ref 13/10

Consent Form

Project title: Over-the-head or from-the-side – does the position of the paramedic performing external chest compression influence the quality of cardiopulmonary resuscitation? A simulation study.

Project Supervisor: Dr Chris Whatman

Researcher: Paul Davey

○ I have read and understood the information provided about this research project in the Information Sheet dated 23rd November 2012.

○ I have had an opportunity to ask questions and to have them answered.

○ I understand that I may withdraw myself or any information that I have provided for this project at any time prior to completion of data collection, without being disadvantaged in any way.

○ I am not suffering from heart disease, high blood pressure, any respiratory condition (mild asthma excluded), any infection, any illness or injury that will impair my physical ability to perform two minute cycles of external chest compressions over a 20 minute period

○ I agree to follow all safety instructions

○ I agree to take part in this research.

○ I wish to receive a copy of the report from the research (please tick one): Yes ○ No ○

○ I wish to have my personal performance results returned to me in accordance with right 7 (9) of the *Code of Health and Disability Services Consumers' Rights* (please tick one) Yes ○ No ○

Participant's signature: .... Date: ....

Participant's name: ....

Participant's email address for research report or personal performance report:

……

Approved by the Auckland University of Technology Ethics Committee on 3rd February AUTEC Reference number 13/10 - and St John Registration Number 009

Note: The Participant should retain a copy of this form.

Paramedic Research

Title: Over-the-head or from-the-side – does the position of the paramedic performing external chest compression influence the quality of cardiopulmonary resuscitation? A simulation study.

UNIVERSITY
TE WĀNANGA ARONUI O TAMAKI MAKAU RAU

Demographics questionnaire

Primary Researcher: Paul Davey   Supervisor : Dr Chris Whatman

Date: / / 2013   Time: ________________   Randomised to: Rescuer 1   Rescuer 2

Age: ≤20   21-30   31-40   41-50   51-60   61-70 (circle appropriate age range)

Authority to Practice   BLS Paramedic   ILS Paramedic   ICP   Years practising __________

Sex: Female   Male   Height ____________cm   Weight ____________kg

Arm length (acromion to first crease of wrist on palmar flexion)   ____________cm

Shoulder to knee height (acromion to superior patella border)   ____________cm

Question: With respect to resuscitation what are the ethical issues that you have faced in practice (general themes – not specifics).

____

____

____

____

____

____

Approved by the Auckland University of Technology Ethics Committee on 3/2/2013 AUTEC Ref 13/10
Approved by St John on 18/04/2013 Ref 009

Paramedic Research

Title: Over-the-head or from-the-side – does the position of the paramedic performing external chest compression influence the quality of cardiopulmonary resuscitation? A simulation study.

What position is best?

ILS and ICP Ambulance staff we want you!

We are interested in partnering with you to validate the over-the-head position for performing external chest compression.

An Invitation

Paul Davey and Chris Whatman are conducting research into the influence of the position of the paramedic performing chest compressions has on CPR quality. This study seeks to validate the use of over-the-head ECC by a crew of two paramedics subsequent to the introduction of the 2010 resuscitation guidelines. Analysis of CPR quality, including ECC rate, depth, hand position, rescuer lean-hand release and chest compression fraction, will be undertaken in a simulated environment; your time commitment will be 45-60 minutes. You will work in pairs and participate in two 2o minute simulated cardiac arrest scenarios – in one you will perform chest compressions from over-the-head, in the other you will perform chest compressions from-the-side.

- We are targeting ILS and ICP working paramedics
- Participation in this research project is voluntary and you may withdraw at any time
- As a participant your results will only be known to the researcher and yourself.
- Get on board and help lead paramedic centric research in New Zealand

If you want to engage please email Paul, paul.davey@aut.ac.nz . He will send you a Participant Information Sheet and establish a time for you to participate

Whom do I contact for further information about this research?

RESEARCHER CONTACT DETAILS:

Paul Davey: please email Paul – paul.davey@aut.ac.nz, or phone 09 921 9999 ext 7155.

PROJECT SUPERVISOR CONTACT DETAILS:

Dr Chris Whatman, chris.whatman@aut.ac.nz, 09 921 9999 ext 7647

Approved by the Auckland University of Technology Ethics Committee on 3/2/2013 AUTEC Ref 13/10
Approved by St John on 18/04/2013 Ref 009