Helicopter winching; Time off chest when performing CPR, manual compressions versus mechanical.

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Conflict of interest

No conflict of interest declared from the author or any participants of this research.

Contents

Introduction

In the United Kingdom (UK) Her Majesty's Coastguard Search and Rescue (HMCG SAR) helicopters are an integral part of the countries emergency service response[1] (Maritime and Coastguard Agency (MCA), 2021). They provide Paramedic level care to critically ill and injured people in a number of hazardous and remote environments such as mountains, boats, cargo vessels, beaches, cliffs and islands. Other than the military, the SAR (Search and Rescue) aircraft are the only helicopters in the UK with patient winching capabilities, which is an important but niche part of pre hospital emergency medicine.

The intention of this research is to identify the time off chest when winching a patient in cardiac arrest into a helicopter. The comparison will be between current practice of manual compression delivery where possible, versus a mechanical chest compression device (Schiller Easy Pulse). The secondary outcome will look at the quality of chest compressions in both groups. This will be measured against the resuscitation council guidelines recommended 5-6cm depth of compressions[2]. Anything less than or greater than this will be regarded as poor quality.

Cardiac arrest is one of the most time critical medical emergencies and survival rates are extremely low, around 7-8%[3]. This could be for many reasons but two of the most commonly researched and concluded to be integral to survival are the hands off chest time and quality of compressions delivered[4]. Both these elements are performed to achieve and maintain intravascular pressure to perfuse tissues[5]. It takes multiple compressions to obtain and continual compressions to sustain this pressure. Therefore, any time when compressions are not being delivered the brain, heart and lungs are being deprived of oxygen, consequently, compromising the patients chance of a neurologically intact survival[6].

The SAR helicopters can cover a distance of 300 nautical miles[7]. Consequently, patients can be in the onboard paramedics care for extended lengths of time and those in cardiac arrest may benefit from equipment, such as mechanical chest compression devices to deliver continuous, good quality chest compressions. The UK resuscitation council guidelines advise their use for situations where manual compressions are not possible or compromise the clinicians safety[8]. SAR winch paramedics are currently faced with these conundrums but have no mechanical device on board to assist them. Following on from results of previously conducted trials this study is going to look specifically at the compression fraction of patients in cardiac arrest, when they are being winched into a SAR helicopter.

The reality of providing medical care in aviation is challenging but equipment and training advancements are improving patient outcomes[9]. This SAR specific research is important due to the niche situations and patient groups winch paramedics encounter, their limited access to assistance and prolonged journey times to definitive care. Published data around manual chest compressions and mechanical devices are largely conducted in hospital settings[10] rarely finding significant benefit to mechanical devices, as most scenarios facilitate optimum space, clinicians and use patient survival as an end point[11]. However, in more recent years there has been an increase in pre hospital data which alludes to an improvement to the quality of chest compressions when delivered mechanically, especially whilst in a moving ambulance or helicopter[12]. Mechanical devices have proven beneficial in allowing clinicians a hands-off approach, assisting in the management of all other clinical, rescue and transportation requirements[13]. For this element alone, this research is required to establish if a mechanical chest compression device has a place in UK SAR.

Due to the variety of mechanical devices available, a SAR specific none scientific trial was conducted prior to this project to find the most appropriate device for the environments encountered by winch paramedics. The trial compared the LUCAS, Zoll Autopulse and Schiller Easy Pulse. The devices were assessed as to their compatibility with stretchers, winching equipment, aircraft avionics and environmental conditions including snow, sand and water. The results of this trial nominated the Schiller Easy Pulse to be the most appropriate device for a SAR environment and therefore will be the mechanical compressor device used for this scientific trial.

Due to the nature of SAR it is hypothesised that the compression fraction and quality of compressions will be closer to those recommended by the Resuscitation Councils 2021 guidelines for best practice in the mechanical group than manual.

Literature Review/Background

Chest compressions, are they important?

Every year in the UK over 30,000 people will suffer an out of hospital cardiac arrest[14] (OHCA). Chances of survival are fewer than 1 in 10, with only 7-8% surviving to hospital discharge[15]. These statistics are significantly better in Seattle, USA, with survival figures of 56% due to their focus on many 'marginal gains' including good quality, continual chest compressions[16]. Their parameters for 'good quality' are adequate depth, full chest wall recoil and minimal interruptions[17]. Cheng, et al (2015)[18] found that, when measured, achieving these requirements is overestimated (Mean difference, range of depth 16.1%-60.6%, rate 0.2%- 51% and compression fraction 0.2%-51%) by care providers and consequently patient care is unconsciously compromised. This research will provide data showing the reality of patient care when winching, which will facilitate and help to improve the delivery of care in this unique situation.

In 2012 the British Heart Foundation (BHF) set out to encourage the public to perform compression only cardio pulmonary resuscitation (CPR) in an attempt to improve the suboptimal 30% bystander CPR compliance rates in the UK[19]. A study involving 4493 patients found a favourable survival of 13.3% for those who received bystander compression only CPR in comparison to 7.8% who received the traditional 30:2 CPR in the pre hospital setting[20]. A meta analysis of three randomized controlled trials (RCT) also found that compression only CPR had favourable survival outcomes in comparison to the 30:2 traditional CPR method, however this was much less at just 2.4% and in the secondary meta analysis of seven observational cohort studies no difference in survival was found[21]. A nationwide, population based study of 40,035 patients found that in the younger population and non cardiac related patients, traditional 30:2 CPR is better due to the requirement for organ oxygenation, especially where emergency service response times are prolonged[22]. This also positively correlates to good neurological outcome in comparison with compression only CPR with a 95% confidence interval (CI)[23] A clearer conclusion in a study by Anantharaman (2011)[24] explained that due to the reluctance of lay persons to perform mouth to mouth, due to infection concerns, and the difficulties of instructing 30:2 CPR from an emergency call handler perspective, compression only CPR was better than no CPR and does have a place in pre hospital resuscitation. Although emergency call handler instructed CPR has doubled the number of patients receiving bystander CPR and has resulted in improved cardiac arrest survival, with good neurological outcomes[25], it is not standard practice around the world[26].

A study specifically looking at paediatric cardiac arrest responders found that of 1411 patients, 49.4% (697/1411) received conventional CPR and 50.6% (714/1411) received compression only CPR. This is interesting, since compression only CPR is not currently recommended for paediatric patients due to the higher likelihood of hypoxia being the reversible cause of their arrest. In contrast to paediatrics, the most common cause of arrest in adults is from a cardiac origin, this is due to co morbidities such as heart disease, (a leading cause of cardiac arrest in the UK[27]) from poor diets and un healthy lifestyles[28] therefore compressions are prioritised to support a failing heart.

The common theme from these studies is the importance of performing compressions with minimal interruptions as this enhances survivability[29]. This is currently difficult to sustain whilst winching patients into helicopters and since mechanical devices are available and provide continual compressions, there use for winching should be explored in an attempt to improve patient care and survival.

The deliverance of good quality manual chest compressions depletes over time[30] . Evidence suggests that despite the use of modern devices with visual and audio instructions and guidance to ensure optimal compression depth, speed and decompression time, effectiveness reduces after just one minute[31]. In a study where 68 volunteers delivered CPR for 5 minutes on mannequins, the average number of compressions per minute was 43 in the 30:2 group and 73 in the continuous compressions group. The mean compression depth for the continuous compressions group was 30mm in comparison to 45mm in the 30:2 group, resulting in poorer quality compressions[32]. SAR winch paramedics are often lone working, this study will produce data that can be used to better understand the potential consequences of this in the absence of a mechanical chest compression device. Recommendations for service improvements will be made where appropriate/applicable.

Mechanical devices and survival rates

There are many different mechanical chest compression devices on the market and in use within emergency medicine worldwide[33]. Due to the requirement of evidence based practice, trials involving the various devices have been conducted with most end points focusing on survival figures[34]. An awareness of these results is important for the transparency of this project, which is SAR specific unlike most literature found during the review, focusing on guideline adherence and gold standard care in helicopter winching environments.

The first trial to mention is the circulation improving resuscitation care (CIRC) project which involved 4753 randomised patients. This compared the Autopulse mechanical chest compression device to manual compressions and found 28.6% versus 32.3% sustained return of spontaneous circulation (ROSC) and 9.4% versus 11.0% survived to hospital discharge making the two methods statistically equivalent, however for resuscitation attempts lasting over 16.5 minutes there was a statistically significant benefit to using a mechanical device[35]. The average SAR flight time to hospital exceeds this time by almost double[36]. Next, the Lucas in cardiac arrest (LINC) trial, which compared LUCAS with manual chest compressions and included 2589 patients. The results found 8.1% versus 7.3% (With a risk difference of 0.78%; 95% CI -1.3%-2.8%) survived to hospital discharge, which was not statistically significant[37] . Lastly the Prehospital randomised assessment of a mechanical compression device in out-of-hospital cardiac arrest (PARAMEDIC) trial included 4471 patients and compared LUCAS with manual chest compressions, finding that survival after 30 days was similar in the two groups (6.3% versus 6.8%; adjusted odds ratio 0.86, 95% confidence interval 0.64 to 1.15). It concluded that LUCAS does not improve survival from cardiac arrest in comparison to manual CPR[38].

In line with the results from these trials the European Resuscitation Council (ERC) advocate *considering* the application of a mechanical device to patients in cardiac arrest in their 2021 guidelines, but only in certain circumstances, such as prolonged resuscitation efforts, lack of responders to perform good quality chest compressions and for transporting patients where necessary[39]. Despite this and the above evidence there are still many published papers claiming that mechanical devices provide superior pressure, flow rates and end tidal carbon dioxide measurements in comparison to manual chest compressions[40]. One study even found 83% Vs 0% ROSC rates with a LUCUS Vs Manual compressions[41].

Extrication and onward transport

Incidents SAR winch paramedics respond to almost always involve moving patients due to their hazardous location or aviation requirements (time on scene due to fuel limitations). A study of 36 patients receiving manual chest compressions found that the hands off chest fraction increases from 0.19 to 0.27 (p=0.002) during transport in an ambulance and compressions per minute were therefore also reduced from 94 to 82 (p=0.001)[42]. The quality of compressions was significantly better with mechanical CPR compared to manual[43]. Sunde, Wik & Steen (1997) found the same with 19% v 69% of chest compressions delivered being too weak, when walking with a patient supine on a stretcher and carrying them down the stairs respectively[44]. This study concluded that mechanical CPR, especially when performed on a stretcher adhered more closely to the ERC guidelines. When transporting by air, chest compression quality is further compromised due to the increased complexity of loading a patient in cardiac arrest and lack of space in comparison to a land ambulance[45]. Operator proficiency is important as highlighted in a study that found hands off time is approximately equal to 50% greater during the application phase of mechanical devices in comparison to manual compressions, which therefore impacted on the total hands off time (Manual 2.1±1.3 V LUCAS 2.5±1.6; Autopulse 7.7±14.3). What is important to note as a consequence however, is the quality of compressions delivered. Compression fraction was 21.2±14.5 in the manual group compared to 76.6±35.3 in the LUCAS group, which supports the use of mechanical devices for helicopter transport and conduction of this research project for SAR[46].

Omori, et al, (2013) used logistical regression analysis to examine the efficiency of the mechanical device Autopulse, when used in helicopter transportation of cardiac arrest patients. This looked at the ROSC rates compared to manual compressions. The results found that 30.6% of patients in the Autopulse group vs. 7.0% in the manual group achieved a ROSC, which could be linked to the findings of the aforementioned studies regarding hands off time and quality[47]. The application of Autopulse is more complex in comparison to the LUCAS and users underestimate the time it takes to apply the device[48]. Gassler, Kummerle, Ventzke, Lampl & Helm (2015)[49] documented a total hands off time of 7.7±14.3 with Autopulse versus 2.1±1.3 manual compressions during a scenario involving application of the device, moving to a stretcher and loading this into a helicopter for a 10 minute simulation flight. SAR winch paramedics often work with volunteer coastguard, mountain rescue and RNLI teams, who may not be familiar with mechanical chest compression devices, making the findings of this research an important consideration. Helicopter winching requires more time with less personnel than loading a patient onto a helicopter that has landed, evidence of compression fraction analysis in this arena is required especially since flight time to definitive care is almost always greater than 10 minutes. SAR units in the north of the UK have previously trialled the Zoll Autopulse for use in austere environments, they found the weight, diameter and built in carry sheet were problematic when attempting to carry the device to scene and fit it quickly. This was especially difficult on windy days, where the carry sheet acted like a sail but also on light wind days when the helicopter rotor wash was funnelled directly below the aircraft. They also found the frequency in which the device stopped compressions and required resetting hampered the compression fraction, as to refit the band; all of the stretcher straps had to be undone in order to gain access to the patient. Likewise, the battery compartment location caused similar compression fraction detriment, as when the batteries required changing a similar process was required. This was exacerbated by the cold temperatures and reduced battery life to around 30 minutes opposed to 45, as Zoll advertise.

There are many scenarios SAR winch paramedics are faced with, where cessation of resuscitation is decided on scene, due to the clinical, extrication and flight time/requirements that would be detrimental to the physiology of a resuscitation attempt. Forti et al (2014) reported a case study whereby the resuscitation attempt would have been terminated on scene, had a LUCAS device not been available from the HEMS unit in attendance. The patient had a two hour arrest to ROSC time and was discharged with no neurological deficit[50]. Although there are few examples such as this, for a SAR winch paramedic and other remote emergency response teams the nature of this incident is regularly frequented. This reality acts as further justification for the conduct of this research. Many patients treated by SAR winch paramedics are fit, healthy humans that have experienced unexpected trauma, in the form of an accident leading to injury[51]. They are better placed to make a full recovery, within reason, than those who have multiple medical conditions and subject to the negativities of polypharmacy[52]. Therefore, it seems only fair to give these patients the best possible chance of survival, by providing, as close to gold standard care, as possible using leading technology and equipment to facilitate this, where appropriate.

Transporting patients in cardiac arrest

There is data documenting the significantly reduced survival rates of patients transported by air due to the interruptions of CPR[53]. Another limitation of performing good quality chest compressions in a helicopter is the lack of space[54]. Although the helicopters used within the UK Coastguard are larger than those used by most charity helicopter emergency medical services (HEMS), space is still sparce and 360 degree access to the patient is unachievable. Flight safety requirements for SAR winch paramedics after being winched into the helicopter such as securing themselves, re connecting to the communication system and disconnecting from the winching hook all require concentration, time (estimated to be greater than 5 seconds) and the use of both hands, consequently patients in cardiac arrest could be deprived of chest compressions whilst these things are completed. With emphasis on minimal interruptions to chest compressions, investigating the compression fraction when winching will provide an insight as to the care currently delivered to cardiac arrest patients when rescued by SAR helicopters.

Thomassen, et al (2017) conducted a study with a mountain rescue team in Norway, comparing manual and mechanical chest compression delivery whilst on a snowmobile (moving and stationary). The study concluded, after 48 runs lasting 3 minutes each (plus 16 none-moving runs) that both LUCAS and Autopulse delivered chest compressions without interruption from the vibrations/movement of the snowmobile descending 204m down a 1.1km track and that there was no significant difference in compression rate and depth ($p=0.12$; $p=0.84$), however leaning was significantly higher during the manual, moving conditions potentially effecting chest wall recoil. The snowmobile platform and position of the person delivering chest compressions was much more advantageous than in a SAR winching scenario and therefore is incomparable, but this study still provides reassurance of the device function in extreme environments, such as those faced by SAR winch paramedics[55]. It is particularly useful to know that the device continued to operate in colder temperatures as there are UK SAR bases that operate in temperatures as low as -20 degrees during the winter months.

Los Angeles lifeguards had a similar technological and data collection method to the equipment used for this study. They used a Zoll defibrillator, training pads and the case review system to interpret the outcome of chest compression quality/compression fraction, whilst on the back of a moving boat. The transport time was 30 minutes, which is, on average, the minimum amount of time for a SAR helicopter transfer[56]. The study compared manual chest compressions to the Zoll Autopulse and LUCAS mechanical compression devices and found that on the back of a boat the compression fractions were 99.57%, 95.51% and 98.4% respectively but concluded mechanical devices offer logistical advantages[57]. Sea state and transfer of a casualty off the boat into an ambulance or helicopter was not included, this research will focus on the patient transfer element and combined, a more realistic compression fraction percentage should be made available.

Physiological evidence for current practice

Larsen et al (2010)[58] found that the LUCAS mechanical chest compression device delivered normal coronary perfusion pressures (CPP) and was therefore of benefit to patients requiring coronary angiography and angioplasty. This intervention is required in a majority of patients presenting with ventricular fibrillation (VF) and pulseless electrical activity (PEA) arrythmias[59]. Elbers, et al (2010)[60] looked at the impact of mechanical chest compressions delivered by the LUCAS device, on the microcirculation (which delivers oxygen and nutrients to tissues) in a drowned, hypothermic cardiac arrest patient. The use of side stream dark imaging was used and confirmed that the microcirculation was being perfused, however the indices improved greatly upon ROSC. This does support the importance of perfusion pressure and ability of mechanical devices to achieve optimum percentages. Ryu, Et al (2022) conducted a study looking at just this, using eight pigs a LUCAS 3 and a Schiller Easy pulse. There were four pigs to each device. The pigs femoral peak velocity, femoral artery diameters, blood flow and end tidal carbon dioxide (ETC02) measurements were recorded along with blood pressure, the depth of compressions they were receiving and mean arterial pressure, which was measured with an arterial catheter. The results found that the LUCAS 3 compressions were deeper than the Easy Pulse, 6.80cm Vs 3.297cm but that the ETC02 was lower in the LUCAS 3 group, 19.8mmHg Vs 33.4mmHg, with a P value of 0.001. The femoral peak systolic velocity was higher in the LUCAS 3 group 67.6cm s-1 Vs 55.0cm s-1cm, whilst the systolic and diastolic diameters were larger in the Easy Pulse group; LUCUS 3 0.4, Easy Pulse 0.8. The femoral flow rate was lower in the LUCUS 3 group at 32.55cm3/s Vs 61.35cm3/s. The authors concluded that Easy Pulse had a shallower compression depth and slower peak systolic velocity but had a wider artery diameter and therefore higher blood flow and ETC02 and suggested that Easy Pulse may create and maintain more effective intrathoracic pressure as a consequence[61].

In a SAR environment definitive care could be a significant distance away and superior clinical decision making on scene unattainable. In the UK NHS ambulance service paramedics have 24/7 access to superior clinical support and are able to communicate directly with coronary care and catheter laboratory physicians, to support their clinical decision making[62]. They are not permitted to cease resuscitation in certain patient groups and SAR winch paramedics are bound by the same clinical guidelines[63]. Consequently, patients are moved and resuscitation quality and survival rates deplete. This research may identify a means of reducing the detrimental impact this has on a patient in cardiac arrest by enhancing the quality of care and consequently chances of survival.

How long is too long?

Some patients SAR winch paramedics respond to can be over an hour and a half flight time away, without factoring in the response and rescue/winching time. A study involving 1035 cardiac arrest patients over an eight year period found that the 99th percentile CPR range for survival was 32 minutes for shockable rhythms, 34 minutes for PEA and 28 minutes for asystole, none of the patients survived after 44 minutes in all rhythms (CI=95%)[64]. Another study included 1014 none traumatic out of hospital cardiac arrest patients the median time of patients who failed to achieve ROSC was 17.5 minutes[65], 10.5 minutes different to the previous study mentioned. The second study time scale is in line with the 2006-2021 clinical guideline times for a 20 minute resuscitation attempt duration. The first explains the very recent change in October 2022, when the UK Resuscitation council and JRCALC amended the 2021 guidelines, from 20 minutes of advanced life support (ALS) to 30 minutes[66]. This still doesn't encompass those patients presenting in a shockable rhythm or PEA, however the modified Rankin scale of those surviving after this time was below 3. It was also documented that the number patients were achieving on this scale declines rapidly after every minute of the onset of cardiac arrest[67]. Another study involving 95,537 patients found 64,339 (48.5%) achieved a ROSC and 9,912 (15.4%) of out of hospital cardiac arrest patients survived to hospital discharge. Patients achieving ROSC had a median duration of resuscitation of 12 minutes (IQR 6-21) which is significantly shorter than the previous study. The median non survival time however was 20 minutes (IQR 14-30) which is 2.5 minutes longer than the previous study, but the IQR encompasses their median time of 17.5 minutes. Patients in this study who had an in hospital cardiac arrest were resuscitated for 25 minutes (IQR 25-28) and had a higher likelihood of achieving ROSC (adjusted risk ratio 1·12, 95% CI 1·06–1·18; p<0·0001) and survival to discharge (1·12, 1·02–1·23; 0·021)[68]. The difference between out of hospital and in hospital survival figures requires further research, consideration as to whether the patient movement involved in the pre hospital setting is the cause of lower ROSC rates is present and further supports the justification for this project. The time from a patient collapsing to a health care professional (HCP) arriving on scene, initiating care, packaging the patient, transportation and the journey time to hospital needs researching as does the time taken to identify cardiac arrest and initiate resuscitation, in a hospital. Another barrier to the initiation of CPR in the pre hospital setting is the detection and diagnosis of cardiac arrest by witnesses/bystanders. A study involving 138 bystanders found that 63 (45.3%) of them did not detect cardiac arrest[69]. The duration of detection and initiation of the process required in the pre hospital setting could be a single or contributing factor to poorer prognosis in pre hospital cardiac arrest patients rather than, more so or less than the detriment to the compression fraction the pre hospital environment presents. This would be an interesting topic for future research.

The requirement to gather a history, assess the patient, their best interests and consider the safety of everyone involved, under tight time constraints at night in precarious situations and with no clinical support, makes a SAR winch paramedics role unique. Performing chest compressions concurrently may prove futile and dangerous. Mechanical chest compression devices have been praised in some studies for the hands off ability and head space they afford paramedics on scene[70].

Perhaps something SAR winch paramedics would benefit from in order to acquire a history, complete other clinical interventions such as securing an airway, ventilating a patient and gaining IV access along with the aviation, rescue and safety aspects of the job.

A literature review from 2021 found ‘continual good quality chest compressions to be the only method of resuscitation that positively impacts prognosis’[71]. This alone supports the requirement to conduct this research, and if proven beneficial, an expectation of the introduction of a mechanical chest compression device into UK SAR clinical practice.

Special circumstances

In a mountain rescue scenario, resuscitation can be with-held or discontinued (excluding special patient groups, such as hypothermia) if the patient has absent vital signs and the risk or extreme environment poses a danger to the rescuer[72]. On average UK SAR helicopters are deployed to 424 rescues in the mountains each year[73]. It is in these environments that most patients become hypothermic and therefore resuscitation efforts must be continued to definitive care[74]. Guideline adherent CPR in the mountainous environment, especially involving helicopters, is limited as is available research[75]. Gordon et al (2015)[76] developed guidelines for hypothermic cardiac arrest patients, which state mechanical chest compression devices should be used and compression interruptions avoided. This work was based upon evidence sourced from a literature review involving 109 articles.

During the winter months there are frequent avalanche taskings in the northern UK SAR bases. Victims of these emergencies require prolonged resuscitation and extracorporeal membrane oxygenation (ECMO) at specialist centres across the country[77]. To give a patient the best chance of survival to definitive care the use of a mechanical chest compression device is advised[78]. Figures as high as 45% survival from out of hospital cardiac arrest and 60% in hospital have been shown with the use of mechanical chest compression device and ECMO-CPR (E-CPR) in hypothermic patients, with half of the survivors demonstrating good neurological status[79]. Furthermore, the optimal time to initiate ECPR is within 60 minutes of cardiac arrest and favourable outcomes are only possible if good quality chest compressions are delivered consistently from the time of collapse[80]. In a SAR environment this would be almost impossible without the aid of a mechanical chest compression device.

Half of the UK SAR bases are predominantly maritime and see significant incidents involving coastal emergencies. Immersion in cold water, leading to hypothermia require prolonged resuscitation attempts as with avalanche victims[81]. A mechanical chest compression device would be beneficial in these scenarios to facilitate quality resuscitation during transportation to definitive care[82]. The UK is surrounded by some of the worlds busiest shipping lanes and consequently UK SAR helicopters frequently respond to patients that are only accessible by winching to and from ships. For a patient in cardiac arrest the time required to move a patient to the winching area for recovery to the helicopter is far greater than the maximum time off chest period, defined as minimal interruptions of no more than 5 seconds by the UK resuscitation council and consequently detrimental to patient care[83].

Refractory cardiac arrest poses a logistical challenge for a winch paramedic due to the requirement to provide gold standard care during extrication and transport as a single responder. The CHEER trial (mechanical CPR, Hypothermia, ECMO and Early Reperfusion) is a single centre prospective, observational study conducted at the Alfred hospital and included 26 patients. 11 of these suffered an out of hospital cardiac arrest but with the use of a mCPR device (Zoll Autopulse) and ECMO at definitive care 96% of patients survived and 54% of these had full neurological recovery (CPC score 1)[84]. These findings and those from a literature review by De Charriere et al (2021)[85] support the requirement of this project as all of the above findings support the use of a mCPR device for patients that SAR winch paramedics frequently attend.

Paediatrics patients in cardiac arrest must be transported to definitive care and cannot be declared dead on scene, unless there are injuries incompatible with life[86] [87]. For SAR winch paramedics, the rescue element of this patient group is further complicated by the presence of a parent or guardian that will almost always, also need rescuing. It is also beneficial for both the parent/guardian, patient and hospital staff to have the parent present. This not only assists with history taking but it has been proven to help the parent/s/guardian in the post incident processing[88]. To facilitate this safely a Schiller Easy Pulse may benefit the patient as it ensures continual chest compressions and affords the winch paramedic time to concentrate of affecting a safe rescue of all involved. LUCAS 3 is contra indicated in this patient group however the Easy Pulse can be used on a child if they meet the chest circumference and width stated by Schiller (Chest circumference smaller than 76cm or larger than 135cm and chest width is smaller than 22cm or larger than 40cm)[89]. However, the Easy Pulse does not have a 15:2 setting, so continual or 30:2 compressions would have to be used, which given the importance of time on the chest and the potential inability to achieve this whilst winching and organising the rescue of others, this could be an alternative worth researching further.

Pregnant patients in cardiac arrest require ongoing resuscitation to definitive care as, ideally, they need an emergency hysterotomy which seldomly can be done at scene[90]. This is especially difficult to achieve in the environments SAR winch paramedics frequent since this procedure should ideally be performed within 4-5 minutes of the cardiac arrest[91]. Effective chest compression delivery is particularly difficult in pregnant patients due to anatomical, hormonal, mechanical and circulatory changes[92]. Manual displacement of the uterus is recommended, however for a SAR winch paramedic, this would be difficult to achieve due to lone working and potential rescue requirements[93]. A mechanical device would seem a good solution to overcome these challenges, however pregnant patients should not be lay supine as this compresses the aorta and inferior vena cava, subsequently restricting blood flow[94]. Unlike the LUCAS and Zoll Autopulse, the Schiller EasyPulse will continue to operate at an angle, even when attached to a patient in a seated position. Therefore, the recommended left lateral tilt position can be achieved concurrently with continuous chest compressions, making it the device of choice in this patient group for further research.

With an ever increasing bariatric population, consideration of the ability and effectiveness chest compression delivery would be for a SAR winch paramedic is required. There are some similar anatomical and pathological barriers to providing effective compressions in bariatric patients, as in pregnant patients, however the device options differ. The ridged design of the LUCAS and safety mechanism will prevent the machine from either being fitted or from functioning if a patient is too large. The Schiller Easypulse however will physically fit if the straps do, but there is a product specification for guide size, which is greater than the frame width of the LUCAS. The Easy Pulse device would therefore be of greater benefit to a larger number of patients in comparison to the LUCAS. Further investigation into other mechanical devices capabilities would be beneficial for this patient group.

Methods

Literature review Method

A Cochrane Population, Intervention, Comparison and Outcomes (PICO) table was created to identify and clarify the search criteria for published studies relevant to the hypothesis (See appendix 1). The population of included data was those involving humans in cardiac arrest. The intervention after CPR must have been a mechanical chest compression device. The comparison was the compression fraction between manual and mechanical compressions and the outcome of interest was the compression fraction and quality, which was measured by looking at the compression depth in both groups.

Once these requirements had been obtained a literature search was conducted (See appendix 2). Three search engines were used. PubMed, The Stavanger University Library and Google Scholar. An advanced search with all of the words ‘cardiac arrest’, the exact phrase ‘mechanical chest compression device’ with at least one of the words ‘manual CPR’ and without the words ‘in hospital’ was then conducted on each database. Initially 6,890 articles were returned. The dates of publication, between 2000 and 2022 were then used to contemporise the results. There were 82 articles remaining. PubMed 42, Stavanger University Library, 33 and Google Scholar, 7. Next a framework for reporting systematic reviews was used.

The purpose of systematic reviews is to discover high quality research and data in an attempt to answer a specific clinical question. The review must be transparent and facilitate reproduction of the search, which enables critique of the research and ensures reliability of the findings[95].

A Preferred Reporting Items Systematic review and Meta Analysis (PRISMA) flow diagram was used to record the findings of the three literature reviews (See appendix 3). The first step documents the total number of reports found from each search engine and those removed before screening with rationale for this. Duplication was the main reason for removal where 11 articles were retrieved by more than one engine.

In total 68 reports were screened, 28 removed. The remaining 40 were sought with 9 unobtainable due to being either no longer available or payment for the article required. The 31 remaining articles were reviewed for eligibility. Three were removed as they used porcine models, one as it focused on valve replacements and two due to them being airway hypothesis rather than cardiac. 25 studies were then included, the full reports were read and relevant background information and research gained as a foundation for this paper.

Method of conduct for the data collection

Permission and winch paramedic recruitment

Application to the Norwegian Social Science Data Service (NSD) was made (See Appendix 4) and information and consent forms designed (See appendix 5). These were then sent out to SAR winch paramedics at Inverness, Caernarfon and Newquay SAR bases. The initial plan was to invite all SAR winch paramedics to participate, however time and aircraft availability prevented this. 5 winch paramedics at three SAR bases responded and agreed to take part in the data gathering, completing the consent forms accordingly. These were then kept secure until the end of the data collection period and then destroyed in a confidential shredder.

Helicopter type and trial setting

Aircraft- Inverness- AgustaWestland AW189 with two pilots, a winch operator and winch paramedic. Caernarfon and Newquay- Sikorsky S-92A with two pilots a winch operator and winch paramedic.

Winching- This was conducted at the airfields of Inverness, Caernarfon and Newquay airports with clearance from air traffic control.

Number of serials conducted

To establish the number of winches needed to obtain statistically significant results a power calculation was completed and revealed 74 as a total required. Due to the time restraints and cost of achieving this it was decided that as many as practicably possible would be done, so as not to negatively impact the delivery of an emergency service.

Equipment and data recording

A titanium stretcher (LSC) carried on all UKSAR helicopters was used and kitted as standard with floats, securing straps, a vacuum mattress, blanket, and casualty mega mover. A mannikin (torso only) compatible with mechanical chest compression devices was used. A Zoll X series monitor defibrillator and Symbio code simulator was used with Zoll training defibrillation pads and data collection puck. All evolution rhythms were asystole. The torso was secured in the stretcher as a patient would be. A Schiller Easy Pulse chest compression device was used for the mechanical evolutions. A hi line rope to prevent the winch paramedic and stretcher from spinning was used on every evolution. All winch paramedics wore their flight suits, lifejackets and winching harnesses along with body protection and helmet. Communication was available at all times via a Polycon radio between the winch paramedic, helicopter crew and hi line tender.

Experimental protocol

The stretcher started on the ground with a winch paramedic in attendance. The aircraft then positioned into a safe winching position, conned by the winch operator. The winch paramedic once hooked on and ready, gave a positive 'winch in' signal and commenced chest compressions on the mannikin. The lead researcher was utilised to tend the hi line for all winching evolutions. This also facilitated standardisation. Once at the aircraft door a cabin entry was conducted, once inside the helicopter the data recording was stopped. This evolution was repeated five times. The next five evolutions were conducted exactly the same as with manual compressions, except the Schiller Easy Pulse mechanical chest compression device was used. The device was fitted by the lead author and checked for correct placement after each evolution, this was to avoid user error and an attempt to achieve standardisation for every winch. This study was not looking at the application of the device, merely just the winching aspect. The data captured from each winching evolution was downloaded from the Zoll and reviewed in Zoll case study. Statistical testing of the data was then conducted to ensure validity and reliability of the results.

Statistical testing

The data collected was continuous and consisted of two independent types, manual and mechanical. Initially a two tailed T test was to be used, however the mechanical data was skewed and manual symmetric, therefore the Man Whitney U test was applied to ascertain the statistical significance of the results. Confidence intervals were also used to verify the distribution of the data. SPSS statistics was used to produce box plots and histograms, which provided a clear visual interpretation of the results.

Results

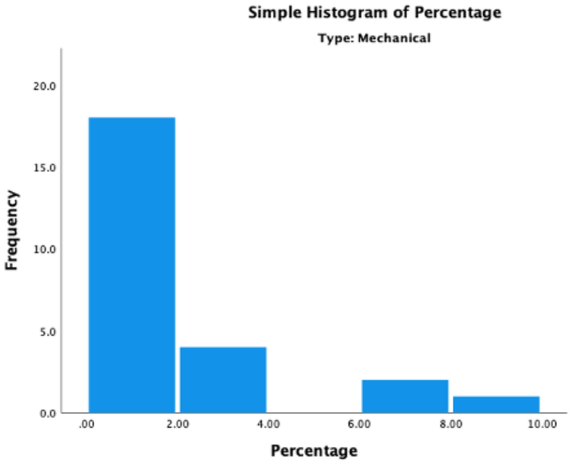
The research data results revealed that the compression fraction is much greater in the mechanical group than the manual group. The percentage of the total time, in which no chest compressions were delivered, was greater in the manual group compared to the mechanical group. The minimum time off the chest was 0% in the mechanical Vs 22.68% in the manual group and the maximum amount of time off the chest was 9.42% Vs 86.73% respectively.

The results show that the mean percentage of time off the chest in the mechanical group was 1.68% with a 95% confidence interval (CI) of 0.59-2.77 Vs 40.84% with a 95% CI of 35.00-46.68 in the manual group.

This research was conducted at three different airfields in benign weather conditions during daylight hours, unlike most SAR taskings, were weather and visibility are considerably less favourable, yet, it was still evident that the delivery of manual chest compressions was much more difficult and intermittent in comparison to the mechanical evolutions. This was seemingly due to the winch paramedics other job requirements to ensure safety of the aircraft, patient and themselves whilst overcoming the force effects from the rotor wash and noise pollution. The inability of the winch paramedic to continually deliver chest compressions due to these environmental and task demanding factors is reflected in the results.

The histograms in figure 1 represent the frequency distribution of the data collected for both manual and mechanical groups. The shape of the histogram depicts the manual data as being symmetric and mechanical, asymmetrical or skewed. The mechanical data has a right skewness, meaning, the outliers are in this direction and are positive. This can be quantified as a representation of the extent to which a given distribution varies from a normal distribution. The symmetric distribution of data in the manual group depicts that the mean, median and mode all fall around the same number. The histograms also depict the standard deviation, which is much greater in the manual group than the mechanical. Figure 2 shows the numerical data of the histogram display.

Figure 1



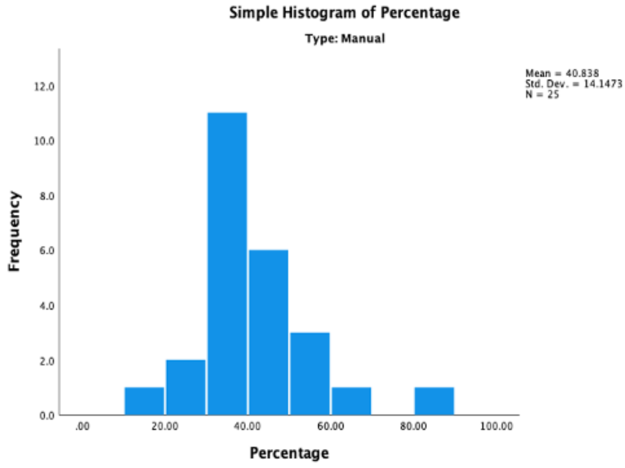


Figure 2

Descriptives[a]

			Statistic	Std. Error
Percentage	Mean		1.6764	.52756
	95% Confidence Interval for Mean	Lower Bound	.5876	
		Upper Bound	2.7652	
	5% Trimmed Mean		1.3651	
	Median		.0000	
	Variance		6.958	
	Std. Deviation		2.63780	
	Minimum		.00	
	Maximum		9.42	
	Range		9.42	
	Interquartile Range		3.00	
	Skewness		1.767	.464
	Kurtosis		2.476	.902

a. Type = Mechanical

Percentiles[a]

		Percentiles 5	10	25	50	75	90	95
Weighted Average (Definition 1)	Percentage	.0000	.0000	.0000	.0000	2.9950	6.9560	8.7240
Tukey's Hinges	Percentage			.0000	.0000	2.5600		

a. Type = Mechanical

Descriptives[a]

			Statistic	Std. Error
Percentage	Mean		40.8380	2.82946
	95% Confidence Interval for Mean	Lower Bound	34.9983	
		Upper Bound	46.6777	
	5% Trimmed Mean		39.7746	
	Median		38.2600	
	Variance		200.146	
	Std. Deviation		14.14730	
	Minimum		17.98	
	Maximum		86.73	
	Range		68.75	
	Interquartile Range		16.35	
	Skewness		1.396	.464
	Kurtosis		3.532	.902

a. Type = Manual

Percentiles[a]

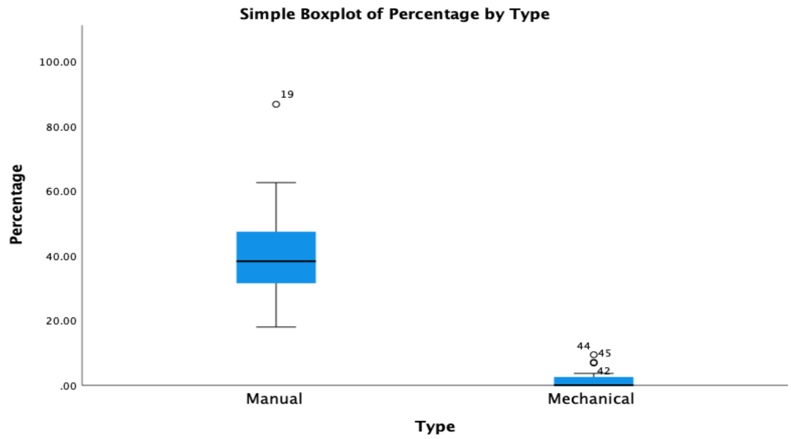
		Percentiles 5	10	25	50	75	90	95
Weighted Average (Definition 1)	Percentage	19.3900	25.0260	31.3900	38.2600	47.7400	57.4580	79.4820
Tukey's Hinges	Percentage			31.4700	38.2600	47.4100		

a. Type = Manual

The significant difference in the compression fraction between the two groups is visible in the box plot (figure 3) where the percentage of time that no chest compressions are delivered during winching is much higher in the manual group than in the mechanical group. In the Mechanical group the percentage of time off the chest ranged from 0% to 9.42% Vs 22.68% to 86.73% in the manual group. Human inconsistency is also evident here with a greater range, variance and therefore standard deviation in the manual group than the mechanical. The impact this would have on a patient is significant and the lack of standardised care, substantial.

Figure 3

Boxplot to show the percentage of time off the chest when compressions were delivered manually and mechanically



Due to the mechanical data being skewed and the manual data symmetric, a nonparametric test of the null hypothesis (Figure 4) was conducted to determine the statistical significance of the results. The Mann-Whitney U test (Figure 5) revealed that the results are statistically significant <.001 and therefore the compression fraction is indeed greater when the Schiller Easy Pulse mechanical chest compression device is used for delivering chest compressions whilst winching a mannequin into a helicopter.

Figure 4

Nonparametric Tests

Hypothesis Test Summary

	Null Hypothesis	Test	Sig.[a,b]	Decision
1	The distribution of Percentage is the same across categories of Type.	Independent-Samples Mann-Whitney U Test	<.001	Reject the null hypothesis.

a. The significance level is .050.

b. Asymptotic significance is displayed.

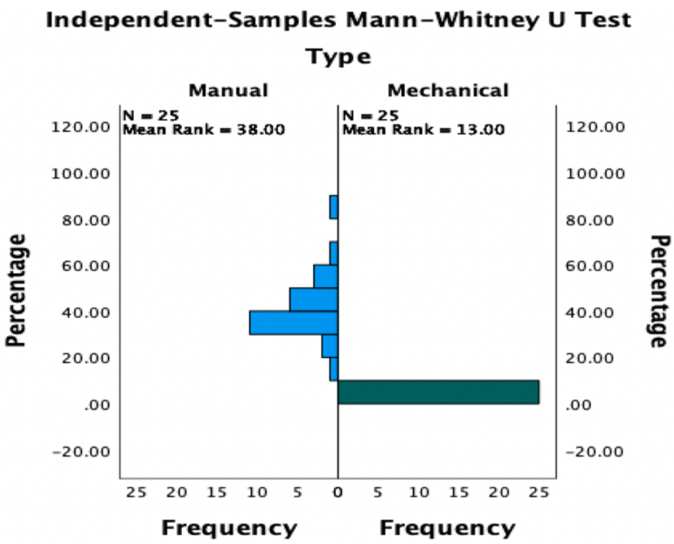
Figure 5

Independent-Samples Mann-Whitney U Test

Percentage across Type

Independent-Samples Mann-Whitney U Test Summary

Total N	50
Mann-Whitney U	.000
Wilcoxon W	325.000
Test Statistic	.000
Standard Error	50.973
Standardized Test Statistic	-6.131
Asymptotic Sig.(2-sided test)	<.001



The Schiller Easy Pulse did not faulter once during any of the winching evolutions, there were no error codes or cessation in compressions, the results recorded are consequently surprising as there were times during the winching evolution where the Zoll compression puck failed to detect any chest compressions. This could be due to the data collection method (puck/Zoll) or the mechanical device. Another theory could be due to the machines initial few compressions being shallower to ensure the machine is safely placed and positioned, which the puck/Zoll may not have registered. Additional research with a larger sample size/more evolutions is needed to investigate this finding further.

Secondary outcome

The secondary outcome of this research was to identify if the compressions delivered mechanically and manually, when winching a mannequin into a helicopter were good quality. The parameter set for this measure was the depth of compressions recorded.

The Resuscitation council guidelines 2021 state compressions should be 5-6cm in depth[96]. Therefore, for this project, compressions meeting this depth were classed as good quality. All compressions less than 5cm or greater than 6cm were classed as poor quality. The boxplot in figure 6 shows the distribution of data and the outliers. The mean depth of the Easy Pulse mechanical device is below the recommended guideline depth. The mean depth delivered manually is within the recommended depth. Both manual and mechanical minimum compression depths were below the recommended 5cm. The maximum mechanical depth was 4.7cm, 0.3cm below the recommended minimum depth. The maximum manual depth was 11.1cm, 5.1cm deeper than recommended. 0% of the mechanical compressions were within the 5-6cm range. In the manual group 24% (6/25) of compressions were greater than 6cm in depth and 48% (12/25) of compressions were less than 5cm in depth. Therefore 72% (18/25) of the compressions delivered manually were outside of the recommended 5-6cm depth range leaving just 28% (7/25) within this range. This result is more adherent with the resuscitation council's optimal compression depth guidelines than the mechanical group.

Figure 6

Boxplot showing the mechanical and manual compression depths in centimetres.

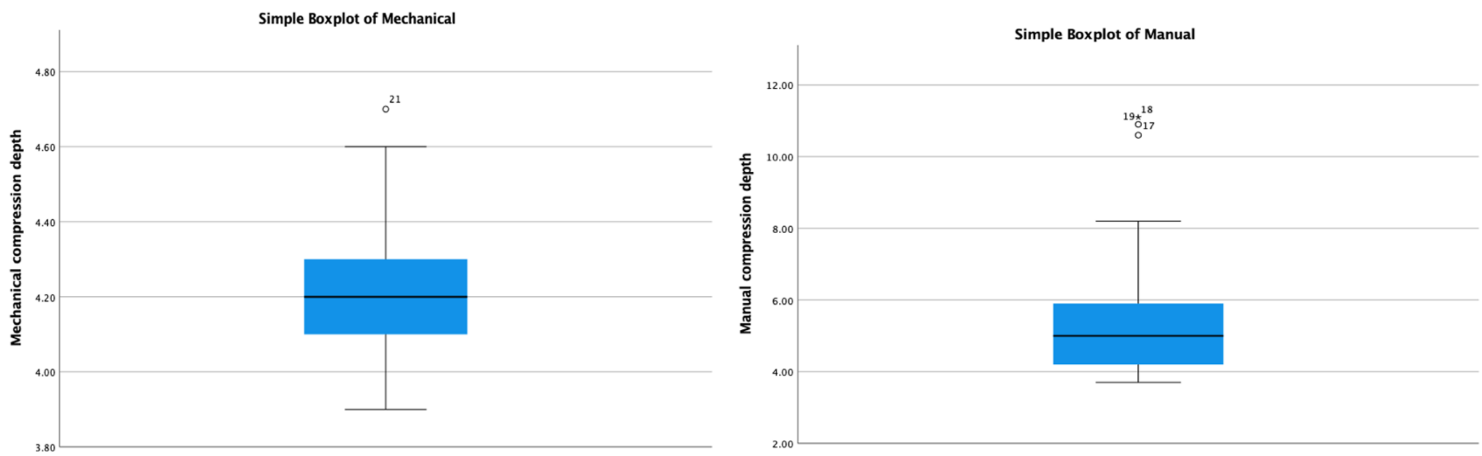


Figure 7

Table to show secondary outcome data; compression depths in the mechanical and manual groups.

	Mechanical	Manual
Mean (cm)	4.2	5.7
Minimum depth (cm)	3.9	3.7
Maximum depth (cm)	4.7	11.1

Figure 8

Rate of chest compressions mean and frequency

Means

Case Processing Summary

	Cases					
	Included		Excluded		Total	
	N	Percent	N	Percent	N	Percent
Mechanical rate	25	100.0%	0	0.0%	25	100.0%

Report

Mechanical rate

Mean	N	Std. Deviation
99.92	25	.277

Means

Case Processing Summary

	Cases					
	Included		Excluded		Total	
	N	Percent	N	Percent	N	Percent
Manual rate	25	100.0%	0	0.0%	25	100.0%

Report

Manual rate

Mean	N	Std. Deviation
98.96	25	7.802

Frequencies

Statistics

Mechanical rate

N	Valid	25
	Missing	0

Mechanical rate

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	99	2	8.0	8.0	8.0
	100	23	92.0	92.0	100.0
	Total	25	100.0	100.0	

Frequencies

Statistics

Manual rate

N	Valid	25
	Missing	0

Manual rate

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	72	1	4.0	4.0	4.0
	86	1	4.0	4.0	8.0
	89	1	4.0	4.0	12.0
	90	1	4.0	4.0	16.0
	93	1	4.0	4.0	20.0
	99	2	8.0	8.0	28.0
	100	6	24.0	24.0	52.0
	101	2	8.0	8.0	60.0
	102	1	4.0	4.0	64.0
	103	4	16.0	16.0	80.0
	104	1	4.0	4.0	84.0
	105	1	4.0	4.0	88.0
	106	2	8.0	8.0	96.0
	109	1	4.0	4.0	100.0
	Total	25	100.0	100.0	

The recommended rate of compressions delivered is 100-120 per minute[97]. Figure 8 shows that the mean number of compressions delivered by the Schiller Easy Pulse was 99.92 with a standard deviation of 0.277. The mean number delivered manually by a winch paramedic was 98.96 with a standard deviation of 7.802. The lowest number of compressions delivered was 72 per minute manually Vs 99 per minute mechanically. 92% of mechanical compressions were compliant with the current guidelines Vs 72% in the manual group. 8% of the mechanical compressions delivered were below the recommended rate at 99 per minute during 2 winches out of the 25 total. 20% of manual compressions delivered were below the recommended rate on 7 winches out of the 25 with rates as low as 72 per minute.

Discussion

The purpose of this study was to establish the time off chest (compression fraction) during the winching of a patient in cardiac arrest into a helicopter when manual and mechanical CPR is performed. This was achieved and despite the small sample size a significant difference between the two groups was found. In comparison to most conclusions in research looking at the same outcome, despite there being very few specifically conducted during helicopter winching, this study shows a huge difference in the ability of paramedics to perform continuous chest compressions whilst moving, in the form of being winched into a helicopter. Other studies have found no differences when performing chest compressions manually Vs mechanically whilst moving on platforms such as boats and jet skis. There were very few studies involving helicopter winching. Some studies comparing the impact on survivability when manual versus mechanical CPR is delivered have shown no significant difference or even a favourable outcome in the manual groups, however these are all in urban settings involving multiple responders. The evidence involving transportation by a HEMS service, which is predominantly a Doctor, Paramedic crew, suggests that if a patient is receiving manual chest compressions, then they have a worse prognosis due to the movement involved with loading, off loading and the limited work space inside the helicopter[98]. The results of this study show much longer periods of time off the chest when the Winch Paramedic is trying to deliver compressions and winch the patient into the helicopter, which supports the work of Pietsch, Et al (2020)[99].

Mechanical CPR has been proven to improve patient care in alpine and coastal environments, this is due to the ability to provide continual compressions despite the difficult transportation usually required in such settings[100]. Despite the importance of ensuring minimal time off chest during resuscitation of patients in cardiac arrest, there have been very few studies performed on the ability to achieve this in austere environments, such as those frequented by SAR winch paramedics[101]. Whilst there have been some studies on winching patients into helicopters and transporting them with on going CPR on the back of boats, the literature review returned zero studies conducted whilst winching patients in cardiac arrest into helicopters and the feasibility of conducting quality chest compressions simultaneously. One military SAR study collected data on winching patients whilst delivering mechanical ventilations, this was a very small sample size of 11 patients but their condition remained stable throughout[102]. One equipment issue was documented, the disconnection of tubing between the patient and ventilator, but this was recognised and resolved during the winch[103]. An Australian HEMS unit also conducted a study focusing on winching ventilated patients, issues with rotor wash were reported, which prevented the bag from inflating, this was resolved with a stiffer bag[104]. An Israeli Air Force rescue helicopter retrospectively reviewed patient data during winching operations and concluded that all patients requiring ventilations should have this mechanically delivered during winching, to free up the winch paramedic/doctor to conduct safe hoist operations[105].

There were no equipment failures during the winching in this study but the rotor wash, which was significantly worse on light wind days, did require the winch paramedic to hold the stretcher on several occasions, to prevent it blowing over as the aircraft was moving into position for winching. This consequently made the winch paramedics ability to conduct manual chest compressions more difficult[106]. Winch paramedics consequently found dealing with the effects of the rotor wash during winching with the mechanical device much easier. The device allowed them to concentrate on the rescue elements and securing the stretcher ready for winching. This is particularly evident in the results, where the mean percentage of time off chest was 40.84% in the manual group Vs 1.68% in the mechanical group of the total winching time. Hollott (2017)[107] conducted a study on winching patients into helicopters and concluded that mechanical equipment such as ventilators are beneficial for affecting a rescue as they free up the winch paramedics capacity to focus on this safety critical element of patient rescue and care. The winch paramedics who took part in this research concur. As indicated in the UK resuscitation council guidelines, using mechanical devices where high quality manual chest compressions are not practical or would compromise the safety of the patient and/or paramedic is advised, this study highlighted the importance of considering this guidance when winching patients in cardiac arrest[108]. Another winching study conducted in Australia found the same benefits to mechanical devices along with the benefit of freeing up a paramedics capacity to focus on other elements of patient care and extrication[109]. SAR winch paramedics have high physiological workload demands and operate at these levels for a moderate amount of time; 81% of V02 peak for 10.2 minutes during water tasks and 86% of V02 peak for 7 minutes when performing land tasks, which supports the requirement to offload physical workload and free up capacity, therefore supporting the use of mechanical chest compression devices[110]. Another proven benefit of using a mechanical device is the consistency of compressions it delivers. It was apparent in this study that the Schiller Easy Pulse was able to deliver compressions at a rate in line with current best practice guidelines much more frequently than a winch paramedic. The frequency of adhering to the guidelines was also higher in the mechanical group. The ability of a rescuer to consistently compress the chest at a rate of 100-120 per minute at a depth of 5-6cm is difficult, due to fatigue[111]. Since the increase of optimum compression depth from 4-5cm to 5-6cm in the 2010 resuscitation council guidelines, the achievement of this has depleted. This is of concern as poor quality chest compressions have a direct impact on survivability[112]. Fatigue was not measured in this study but should be considered when interpreting the results, although the difference between the two groups is such that it wouldn't change the statistical significance.

The use of a hi line prevents a winch paramedic from spinning when being winched[113]. Using the hi line during this study took up the use of one of the paramedics hands. Had a hi line not been used and a spin developed the chances of a winch paramedic conducting chest compressions would have been almost impossible. Using a hi line whilst winching requires a competent person to tend the line, this can be taught relatively quickly by the winch paramedic, but this and the line set up adds time to the rescue and would potentially interfere with uninterrupted chest compression delivery and time on scene[114].

As cardiac arrest is one of the most time critical medical emergencies, it is common practice for medical professionals working on helicopters to be dispatched, however, according to available research, patients transported by air have worse survival rates[115]. This is because of the logistics of loading the patient onto an aircraft and space within the helicopter to perform good quality chest compressions[116].Until recent years patients in cardiac arrest were taken to hospital as a matter of urgency, known now as a 'scoop and run' approach in the pre hospital world, aiming for minimal time spent on scene[117] but still, there seems to be a void in data surrounding the effectiveness of CPR whilst moving a patient and the literature available suggests that transporting patients in cardiac arrest has a negative effect on their survival[118]. The latest guidance, for many pre hospital emergency services around the world, now encourages clinicians to stay on scene to focus on good quality chest compressions amongst other interventions[119]. This may contribute to the marginal, yet positive improvements in the survival rates from out of hospital cardiac arrest[120 121]. However, due to the location of patients SAR winch paramedics attend, this is not always achievable. The results from this study should be considered when the decision to move a patient in cardiac arrest is made as the compression fraction is overwhelmingly greater when a mechanical device is used to deliver compressions in comparison to manual delivery. This statistically significant data should empower winch paramedics to use a mechanical device, which will also afford them bandwidth to affect a safe rescue.

In North America 58% of cardiac arrest patients are transported to hospital, this number is much lower at just 8.3% in Australia[122]. The survival rates are favourable in Australia, even if the onset of cardiac arrest in America happened en route to hospital in the back of an ambulance [123] The resuscitation outcomes consortium found significantly lower survival rates if ROSC was not achieved on scene prior to transportation to hospital[124]. Despite this finding and the lack of empirical supporting data, SAR winch paramedics may have to move patients regardless of the detriment to care. This is usually due to the winch paramedic, patient or aircraft safety and therefore they should have a mechanical device available for use to facilitate continuous chest compression delivery.

Patients achieving ROSC will be transported to hospital, possibly by helicopter but not always requiring to be winched into it. Evidence shows that whilst carrying a patient on a stretcher, chest compression quality is poor, therefore if the patient re arrests en route, having a mechanical chest compression device in place will enhance patient care and survivability[125]. A study involving 626 cardiac arrest patients found 7% of those who sustained a ROSC re arrested in the helicopter en route to hospital and 5% were transported with CPR on going[126]. Although these percentages are low, they do support the requirement for mechanical compression devices on helicopters and this is particularly so in SAR, as there is often only one paramedic on board[127]. Similarly, if a patient requires a prolonged resuscitation attempt, for example a hypothermic patient, a mechanical device will enhance their care as moving from scene to the helicopter and then from the helicopter to hospital will require significant movement, proven to be of detriment to survivability[128]. This is even more pertinent when considering most SAR helicopter flight times are a minimum of 30 minutes in addition to these transfers, leaving just one or two clinicians to perform chest compressions[129]. One in five patients who gained a ROSC and received post ROSC care in hospital, where good quality chest compressions were delivered during transport to the hospital, survived with good neurological outcome in a study involving 2643 patients, conducted over 15 years[130]. This data, along with the compression fraction results of this research paper, are important considerations for SAR winch paramedics when treating patients in cardiac arrest.

The chain of survival required for cardiac arrest patients in the UK is a familiar four stage pictogram, six stage in the USA, (See appendix 6) to emergency care providers. In recent years it has been widely taught in schools and other public sectors to ensure timely treatment of this medical emergency[131]. A study conducted over 19 years, involving 59,926 patients found survival to discharge improved from 4.8-10.7%, over double, post introduction and implementation of the concept[132]. After recognition of a patient in cardiac arrest the next action is early, effective continuous chest compressions, which are proven to increase the chances of achieving ROSC[133]. The apparent variation in compression fraction when conducting winching operations with and without a mechanical chest compression device is compromising this link and consequently patient care. The compression fraction deficit during winching without a mechanical device, undoubtably compromises the second stage of the chain, therefore all patients with ongoing chest compressions that require winching into a helicopter should have a mechanical device attached.

With the results from this study showing a huge disparity between compression fractions of manual and mechanically delivered compressions, it would seem unacceptable to continue to winch patients in cardiac arrest without the aid of a mechanical chest compression device. Despite the small sample size, the results were still statistically significant with >95% confidence intervals. That said, there is some discrepancy in the depth of compressions the mechanical, Schiller Easy Pulse delivers in line with the UK Resuscitation Council guidelines. They are however, just that, a ‘guideline’ and despite them being written from a reliable evidence base, it seems responders are still not always achieving the optimum depth of 5-6cm when performing manual compressions even in optimum environments[134].

Some published data suggests survival from cardiac arrest is more likely when the mean compression depth is deeper, which would explain the increased depth from 4-5cm to 5-6cm in the latest resuscitation council guidelines. However there doesn't seem to be an overriding wealth of evidence to support either depths in relation to survival outcomes. Vadeboncoeur, et al (2014)[135] published data to support the change. His sample size was 593 out of hospital cardiac arrest patients. 136 patients received compressions at a mean depth of 5.36cm and survived Vs 63 patients who received compressions at a mean depth of 4.88cm and died. (CI 53.6 mm, 95% CI: 50.5–56.7 Vs 48.8 mm, 95% CI: 47.6–50.0). The depth of compressions in the mechanical group in this project are consequently of concern and require further research/investigation. That said, only 28% (7/25) winches saw compression depths between 5-6cm in the manual group, with much lower compression fractions so consideration of the bigger picture should be given when interpreting the results of the secondary outcome. Contrary to Vadeboncoeur, et al (2014) findings, Stiell, et al (2014) found that the maximum amount of survivors from cardiac arrest, from a much larger sample size of 9136 out of hospital cardiac arrest patients, received compressions between 4.3cm and 5.53cm in depth with a peak of 4.56cm. These depths are in line with the old Resuscitation Council guidelines. They concluded that the latest guideline target of 5-6cm may be too high[136]. There has also been some concerns as to the damage mechanical devices cause to patients thorax, ribs, sternum and internal organs, however it has been confirmed by autopsy that there are no difference in injuries where patients have been treated with manual Vs mechanical chest compressions[137]

Compressions that are too shallow compromise cerebral perfusion pressure and the maintenance of major organ oxygenation/function[138]. Deeper chest compressions compromise cerebral blood flow, can increase intracranial pressure and cause trauma such as fractured ribs to a patient, further research is needed to ascertain conclusive, evidence around the optimal compression depth[139]. In line with aiming to achieve minimal time off the chest and effect a timely rescue in a hazardous environment, the schiller easy pulse should be used despite the recorded depths it delivered being below the recommended guideline depth.

The definition of 'quality compressions' in this and most other research is predominantly defined by the depth of compressions[140 141]. This is probably because it is a relatively easy, non invasive method of data collection. Research published by Ryu, et al (2022)[142] however, looked at perfusion pressures, invasively and found these to be better in a device with a compression depth of just 3.279cm compared to 6.80cm. Higher perfusion pressure correlates to increased coronary blood flow and is linked to better restoration of circulation[143]. Further research is required to look specifically at patient survival and neurological outcomes from cardiac arrest, when the Easy Pulse is used. It would be interesting to see the impact, if any, shallower compressions but better perfusion might have.

Emphasis on good quality, continual chest compressions at a rate of 100-120 a minute has been proven to improve outcomes from cardiac arrest[144]. From the results of this research paper, it is clear to see that the mechanical device delivered the most consistent compressions at a rate of 99-100 a minute. The lowest number of compressions per minute delivered manually was 72 Vs 99 mechanically. Although the mean numbers were similar the standard deviation in the manual group was much larger than the mechanical, which suggests that the compliance of guideline recommended rate is less frequent. A study including 3098 out of hospital cardiac arrest patients, where 8.6% survived to hospital discharge, found a mean compression rate of 112 ±19. A curvilinear association between chest compression rate and ROSC was found but there was no significant association between compression rate and survival to hospital discharge[145]. 100% of the compressions delivered by the Easy Pulse fall in line with the mean compression depths of this study Vs just 84% delivered manually. Another study involving 10,371 out of hospital cardiac arrest patients looked at the compression rate data but also adjusted for the compression fraction and depth. A global test found no significant relationship between the compression rate and survival (p=0.19) which could afford us some acceptance of the manual and even the slower rate results of the mechanical group in this research however after adjustment for covariates (chest compression depth and fraction, n=6,399) the global test then found a significant relationship between the rate and survival[146]. This supports the importance of this project and the data retrieved surrounding the compression fractions and depths, but leaves requirement for further research to establish which component, if any, impacts survival rates most. Regarding the optimum compression rate, further research focusing solely on this and survival from cardiac arrest is needed.

Another consideration for future research is the application time of the Schiller Easy Pulse and other mechanical devices in the knowledge that the single most contributing factor, to survival from cardiac arrest is continuous, quality chest compressions[147]. LUCAS claim their device takes a median of 7 seconds to apply[148]. A study looking at application times found the Zoll Autopulse to be extremely difficult to apply by a single responder and much more time consuming[149]. Schiller claim the Easy Pulse can be applied by a solo responder, but this needs to be tried and tested to gain an evidence base for other parameters surrounding this, such as the compression fraction during the application.

One advantage of the Schiller Easy Pulse in a SAR environment is its light weight (5kg including batteries) and compact size in comparison to other devices such as the Zoll Autopulse (9.3kg excluding batteries) and LUCAS (8kg including batteries). This makes transporting it to austere environments such as up mountains and onto ships easier. The compression depths of the Schiller Easy Pulse were found to be below the European Resuscitation Council 2021 guidelines in this study. The mean compression depth was 4.2cm, the minimum was 3.9cm and the maximum was 4.7cm (SD 0.21). An interesting study by[150] Roh & Lim (2013) found that mean compression depth was shallower when delivered by underweight nursing students in comparison to normal or overweight students. A similar study concluded that lightweight responders should rotate compression delivery every 1 minute rather than two as their compression depth and fatigue levels were apparent sooner than in heavier responders[151] Therefore, further investigations surrounding the possible impact of the lightweight design may be required. Best practice for delivering chest compressions is to have the patient on a hard surface[152] otherwise the depth is not sufficient to achieve adequate perfusion pressures[153]. There can be a 29.7% depletion in compression depths if they are delivered on a mattress with a reduction to 15.4% if on a hard spinal board[154]. This is still significant and detrimental to the maintenance or achievement of perfusion pressure. Patients being winched into a SAR helicopter are placed into a stretcher, which is metal and contains a vacuum mattress, however once airborne the stretcher moves with the force of compression delivery, thus compromising the continuity of quality care. The results from this study evince this theory, the minimum compression depth delivered by the winch paramedic was 3.7cm, the maximum was 11.1cm and the mean 5.7cm (SD 2.22). The difference in mean compression depths for the manual and mechanical groups was 1.5cm with just 0.2cm difference between the minimum compression depths delivered during the trial (Easy Pulse minimum 3.9cm Vs Manual minimum 3.7cm). The maximum depth was significantly greater in the manual group than mechanical, 11.1cm Vs 4.7cm, which is much deeper than the recommended depth of between 4-6cm.

The literature review results surrounding mechanical chest compression devices retrieved very few studies involving the Schiller Easy Pulse. One conducted in an Austrian alpine setting found that effective compressions (Deep enough compressions) were delivered just 7% of the time in comparison to the LUCAS 3 (98%) and Corpulse CPR (94%) devices and the average (mean, SD) depth was 34mm, 57mm and 53mm respectively[155]. This study concluded that this may be due to the different technologies, the Schiller Easy Pulse being a piston and band combination in comparison to a piston only[156]. The study by Ryu, et al (2022)[157] confirms that the depth of compressions delivered by the easy pulse, although shallower than the resuscitation councils recommended depth, actually achieved better flow rates, end tidal C02 readings and greater velocity within arteries than a device achieving the recommended compression depth (LUCAS). The conclusion was that despite the shallower depth the intrathoracic pressure generated by the 3D technology created and maintained more effective intrathoracic pressure[158]. This research was statistically significant but the sample size was very small. It would be interesting to see the result of this study in a human cohort rather than porcine. The answers to the many questions around the effectiveness of mechanical compression devices are being sought and slowly emerging in publications. An interesting case study comparing vessel perfusion and microvascular flow in a hypothermic patient receiving mCPR and once ROSC was achieved has shown that the heart is still better at perfusing vessels than any external compressor[159]. The percentage of perfused vessels (small) was 64% mCPR Vs 97% ROSC and 75% V 100% in large vessels. Microvascular flow rates were also better once ROSC had been achieved, 1.8% Vs 3.0% in small vessels and 2.2% Vs 3.0% in large vessels. Interestingly SP02 was greater during mCPR than once ROSC had been achieved 96% Vs 80%[160]. Although this is a case study of one patient, access to these figures is becoming increasingly beneficial for advancements in pre hospital care. Such parameters for measuring quality of care and mCPR device effectiveness would make for interesting ongoing research in line with the results of this research and that of Elbers, et al (2010)[161] and Ryu, Et al (2022)[162]. Achieving ROSC is the primary focus for winch paramedics when they attend a cardiac arrest patient. Seewald, Et al (2019)[163] found mechanical CPR to be an independent predictor of ROSC after comparing manual Vs mechanical CPR in 19,609 patients. ROSC was achieved in 51.5% of patients receiving mechanical CPR Vs 41.2% of patients receiving manual CPR (95% CI 48.2-54.8% expected 42.5% Vs 95% CI 40.4-41.9% expected 39.2%) with odds ratio of 1.77; 95% CI 1.48-2.12[164]. Further evidence to support the use of winch paramedics using the schiller Easy Pulse, despite it's shallower than recommended compression depth, in order to achieve ROSC for the provision of adequate tissue perfusion and flow, delivered by the heart.

The author of this paper contacted Schiller regarding the compression depth and the explanation given was regarding the '3D technology', no further evidence based research was provided. Schillers product specifications published on their website do not list the depth of compressions the device delivers. To assist in the elimination of cross contamination the plunger on the Easy Pulse has a one use only cover, which can be changed when service mode is selected. This activates an elongation of the plunger, further than it extends whilst delivering compressions, further research as to whether this could be set as standard to facilitate deeper compression depths as required, would be an interesting topic for future investigation.

In October 2022 the Joint Royal College Ambulance Liaison Committee (JRCALC) changed the minimum duration of a resuscitation attempt from 20 minutes to 30, this further supports the use of the Schiller Easy Pulse by SAR winch paramedics due to them lone working with long transit times to definitive care and/or additional medical support[165].

Most published literature in the medical field involves adult sample populations. A contraindication to stopping a resuscitation effort in the pre hospital setting is if the patient is a paediatric (under 18 years of age)[166]. Most mechanical chest compression devices are contra indicated in the paediatric population. One study looked at the compression depth of manually delivered (by 24 experienced paramedics) chest compressions Vs the CORPULSE device on a five year old simulation mannequin. The conclusion was that the manual compressions were better as they complied with recommended depths of a third of the depth of the chest/4-5cm in comparison to the mechanical device which averaged 7 ± 0.3cm[167]. The LUCAS device was used successfully to resuscitate an 11 year old boy, a blanket was placed under the child to facilitate compliance[168]. The LUCAS device has a built in safety feature, whereby it will not operate if it calculates the patient to be too large or small, although it is designed for adult patients only[169]. This was a case study only, further evidence is required on paediatrics of all ages to establish the benefit, if any, of using LUCAS or any other mechanical compression device in these patients. The Schiller Easy Pulse has been used on paediatric patients, due to the design, if the device physically fits the patient, it can be used. Naturally a child in cardiac arrest is an emotionally stressful situation to respond to and no doubt there will be parents to manage, alongside delivering clinical care[170]. The Easy Pulse would assist the winch paramedic to fulfil their requirement and expectation to deliver continuous chest compressions, effect a rescue, manage the scene, support the child’s family and transport the patient to hospital. Further evidence to support the use of the Schiller Easy Pulse in the paediatric population is required to facilitate evidence based practice.

Clinical research is conducted to enhance patient care and promote recovery from injury and illness[171]. Current evidence tells us that, where chest compressions are indicated, they should be delivered with minimal interruption to achieve the best outcome for the patient[172]. Maximising the compression fraction improves survival to hospital discharge in patients suffering out of hospital cardiac arrest but transporting them poses a challenge to achieving this[173]. We know that mechanical devices provide continual compressions and that they do so much better than humans can when there is a requirement to move and or winch a patient into a helicopter[174 175 176]. We also know that mechanical devices, despite the evidence suggesting they don’t improve survival to hospital discharge, do improve survival to hospital[177]. As mentioned, briefly above, application of these devices takes time however and this should be considered to avoid defeating the point of applying one. A study involving 32 patients found it took a median time of 32.5 seconds (IQR 25-61) to apply a LUCAS, significantly greater than the recommended maximum of 5 seconds and advertised 7 seconds on the LUCAS website. The conclusion was team working and practice was needed to reduce this unacceptable application time[178 179]. The Schiller Easy Pulse was already in situ for this trial but SAR winch paramedics are aware of the importance of a slick application and have devised a step wise approach to apply it. This method takes just 7 seconds of time off the chest and whilst this is still 2 seconds too slow it is an improvement on 32.5. This has not been formally researched, further investigations looking at the application times and procedures along with the potential determent to the patients survival needs investigating. Since most research comparing mechanical and manual chest compressions, where no movement is undertaken, conclude that manual are superior a clinician stabalisation device was trialled. The results found that the device when used in the back of a moving ambulance enabled delivery of chest compressions at a level similar to those in a none moving environment[180]. This would be impossible to facilitate in the back of a SAR helicopter, but shows innovation in attempting to decrease the detriment that transport has on survival rates of patients in cardiac arrest.

Suggestions for further research

With consideration of the results of this research and published data around the compression fractions when moving patients in cardiac arrest, gaps in evidence have become apparent. To close these, human studies looking at the impact of using a Schiller Easy Pulse has to patient survival is needed. This is due to the compression depths being shallower than recommended and lack of background information regarding this technology. This would provide additional data and a more holistic understanding around the findings of the Porcine study, that looked at the perfusion pressures and blood flow when the Easy Pulse and LUCAS 3 were used. Comparisons of different mechanical devices in the same transportation environments (ambulance, helicopter, boat, winching, fixed line underslung load, alpine skidoo, jet ski etc.) would also be beneficial. Application times for devices and how to improve these, possibly devising a step wise approach method specific to each device, for responders to practice and adhere to. This could reduce the time off the chest when fitting devices and would be a beneficial research project. For SAR winch paramedics the ability to perform continuous chest compressions at a high quality isn't only difficult whilst winching. As described throughout this paper they practically lone work for significant lengths of time, which includes the transit time to a hospital. It would therefore be interesting to research the compression fraction comparison of manual Vs mechanical overall, from identification of cardiac arrest to arrival at hospital. This should include moving from scene to the winching position, packaging, winching, cabin entry, transit to hospital, transfer off the helicopter and into an ambulance (for the journey to the emergency department) and then off the ambulance and into the resuscitation bay. This would give an excellent insight as to the reality of the current care and compression fraction SAR winch paramedics are delivering to cardiac arrest patients in these logistically difficult scenarios. Another interesting project would be looking at the total time from the onset of cardiac arrest in the pre hospital setting to arrival at hospital compared to the identification of in hospital cardiac arrest and the initiation of resuscitation. This would `answer the question as to whether survival is due to down time, speed in which resuscitation is commenced, duration in which it is continued and the obstacles encountered from pre hospital to in hospital for those out of hospital patients. This may be a single contributing factor to survival rather than or along side compression fraction and would follow on from the work Goldberger et al conducted in 2012[181].

Limitations

The are several limitations to this study. A power calculation of 74 winches was calculated but only 25 manual and 25 mechanical were actually achieved with just 5 winch paramedics conducting 10 evolutions each (5 manual and 5 mechanical). Due to this mixed model, consideration of fixed and random effects where discussed. The potential for winch paramedic fatigue and practice bias were considered and should/could have been adjusted for, however the results being so different and statistically significant, meant this wasn't necessary as this potential had no impact on the findings.

Bias potential during this study such as poor performance during manual compressions, to favour the mechanical device, should the participant want its introduction to practice, have been identified. Although it was not be possible to link performance to an individual, it was evident at the time of data collection, which may have encouraged participants to perform to the best of their ability during all serials.
There are 10 SAR bases around the UK, sadly due to aircraft availability, SAR taskings and time/cost this study was conducted at just three bases. However, these bases were a good representation of all 10 bases, two being predominantly mountain and one maritime but all three busy, seeing many patients and taskings per year. Consequently, winch paramedics most proficient in the deliverance of patient care due to regular patient contact in comparison to other quieter bases may have been captured. That said, many winch paramedics work on emergency ambulances alongside their SAR roles to prevent skill fade and to retain contemporary cpd portfolios.

The environmental conditions when working under a helicopter have an impact on almost everything. Light wind days make rotor wash incredibly powerful and almost impossible to work under. Exact weather wasn't documented as part of this research as, had it been significant, then the trial wouldn't have been conducted due to risk versus reward. There will have been days where light winds would have affected the winch paramedics task execution ability, which was not accounted for in this study.

Outside air temperature varied from Inverness in Scotland to Newquay in Cornwall which has an impact on a humans ability to complete tasks. This also has an effect on machinery, specifically battery life of machines such as the Zoll and Easy Pulse. No machinery was affected but the winch paramedics ability to perform tasks could have been impacted by the weather/temperatures, which wasn't accounted for in the results.

Winch paramedics have essentially two variants of uniform/personal protective equipment (PPE). In Inverness they wear predominantly mountain clothing, whereas in Newquay they almost always wear immersion suits. There have been studies conducted looking at the deliverance of chest compressions whilst wearing PPE which shows a depletion of ability to deliver quality compressions especially when in an immersion suit. This was not taken into consideration during this trial, a mixture of PPE was worn by winch paramedics in the form of flight suits and additional layers of warm outdoor clothing.

Conclusion

The compression fraction when using a Schiller Easy Pulse is significantly better whilst winching a mannequin into a SAR helicopter in comparison with a winch paramedics manually delivered chest compressions.

It is recommended that cardiac arrest patients that need to be winched into a SAR helicopter should have a Schiller Easy Pulse fitted to deliver consistent chest compressions.

The chest compression depth in the manual group was more adherent to current resuscitation council guidelines of 5-6cm when delivered. None of the compressions delivered by the Schiller Easy Pulse were within the recommended depth range.

Further research into the band and piston, 3D design of the Schiller Auto Pulse is required to obtain a better understanding of the quality of care it delivers to patients in cardiac arrest.

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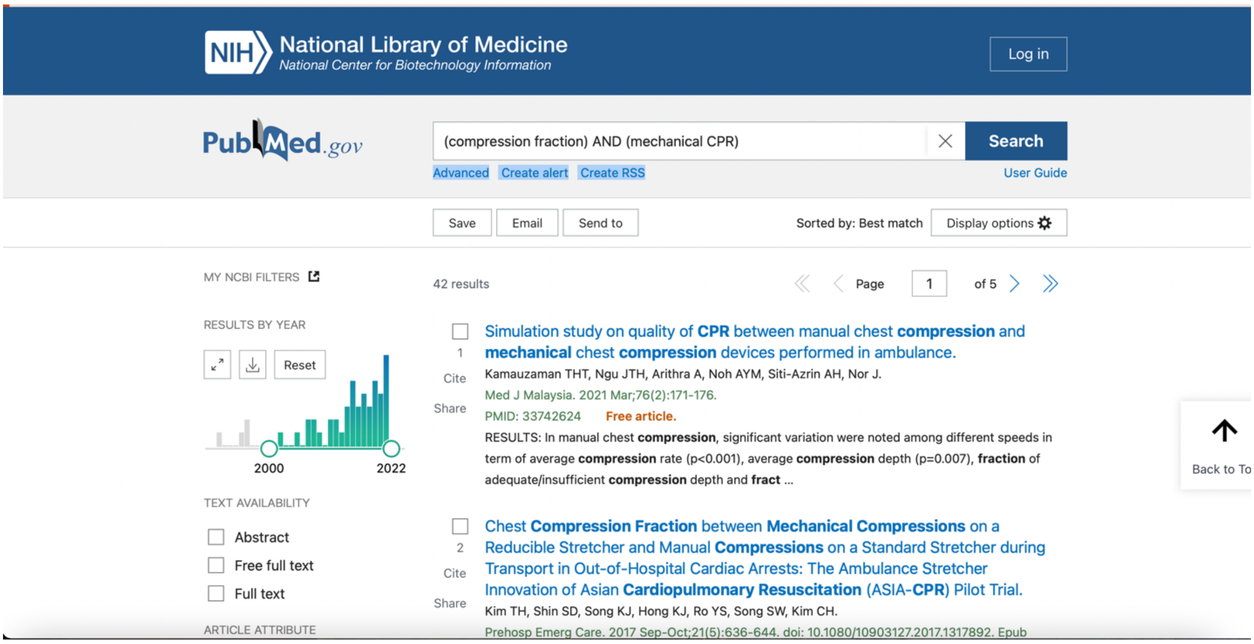
Appendix 1

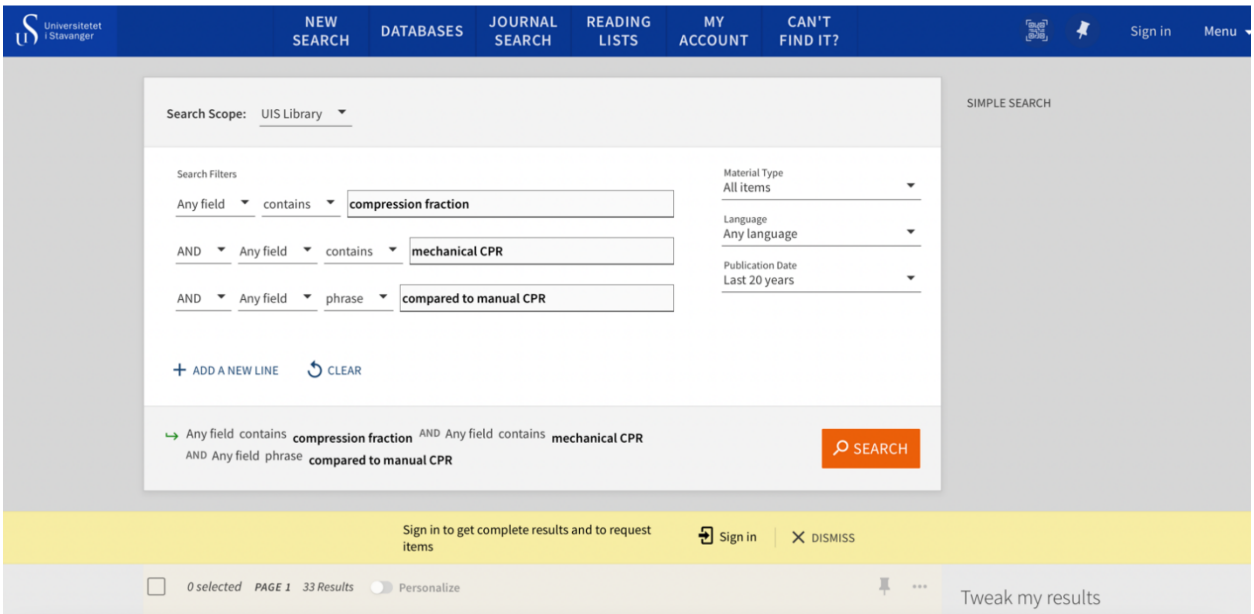
Cochrane PICO search

PICO	
Population	Cardiac arrest
Intervention	Mechanical chest compression device
Comparison	Mechanical chest compression and manual chest compression fraction time when winching into a helicopter
Outcomes	Compression fraction in both groups and Chest compression quality (Depth)

Appendix 2

Results of PubMed and Stavanger University library literature search.

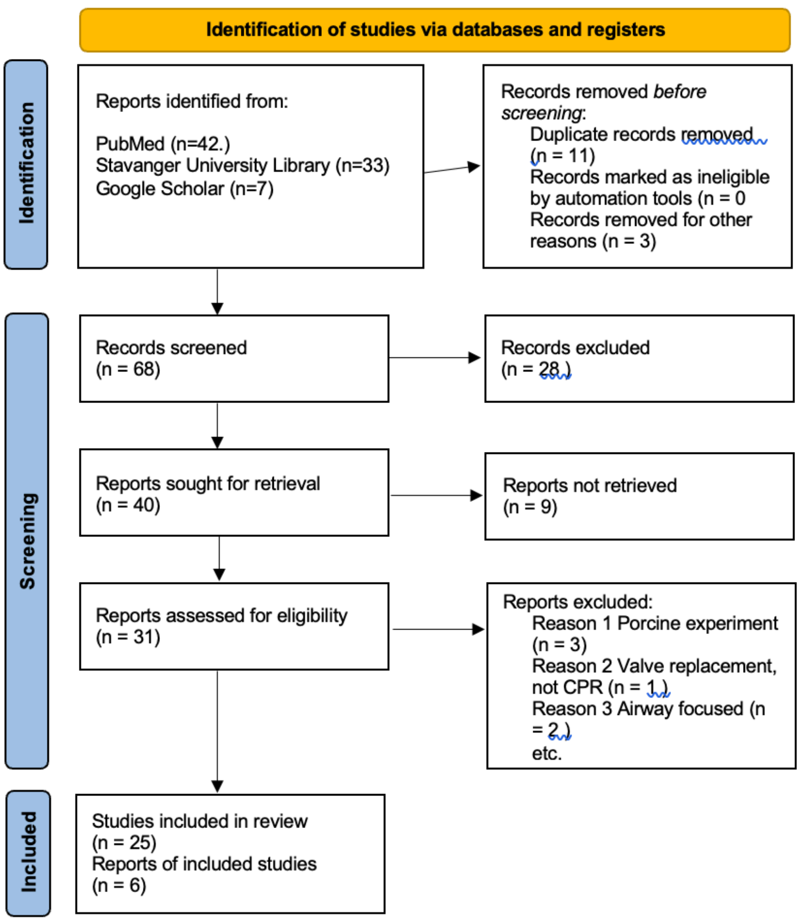




Appendix 3

PRISMA flow diagram of results of systematic literature review.

PRISMA 2020 flow diagram for new systematic reviews which included searches of databases and registers only



From: Page MJ, McKenzie JE, Bossuyt PM, Boutron I, Hoffmann TC, Mulrow CD, et al. The PRISMA 2020 statement: an updated guideline for reporting systematic reviews. BMJ 2021;372:n71. doi: 10.1136/bmj.n71

For more information, visit: http://www.prisma-statement.org/

Appendix 4

NSD application to conduct research

NORSK SENTER FOR FORSKNINGSDATA

Notification form

Reference number

724937

What personal information should you process?

- Name (also by signature / consent)

Project information

Project title

Comparison of hands-off time in manual and mechanical cardiopulmonary resuscitation during helicopter winching

Project description

UK Search and Rescue (SAR) paramedics work in hazardous environments and often have to winch patients into the helicopter. Currently there are no mechanical CPR devices on the aircraft, therefore this project is going to look at the effectiveness of chest compressions as they are currently delivered in comparison to those delivered by a mechanical device. The primary outcome is to compare the compression fraction with manual and mechanical CPR when winching.

Justify the need to process the personal data

The participants will need to sign a written consent form to take part in the research. This form will not be published or shared, but will have their name / signature on it. After this they will be referred to as an unidentifiable letter. This is purely to ensure all participants complete a winching evolution conducting manual chest compressions and using a mechanical device. Only the principal investigator will be able to link their assigned letter to their name. It is not necessary to collect the names, work base location, ages, gender or addresses of the participants as this will not be required to acquire the data needed for the research question.

External financing

Type of project

Student project, master's degree

Contact information, student

Abi Wild, abi000@hotmail.com, tel: +447551007292

Treatment responsibility

Institution responsible for treatment

University of Stavanger / The Faculty of Health Sciences

Project manager (scientific employee / supervisor or research fellow)

Per Kristian Hyldmo, per.k.hyldmo@uis.no, tel: +4741600211

Should the treatment responsibility be shared with other institutions (joint treatment managers)?

no

Selection 1

Describe the selection

Search and Rescue (SAR) Winch Paramedic

Recruitment or withdrawal of the sample

An email will be sent to SAR winch paramedics operating for the HM Coastguard in the UK via their works email. This will include a background and an explanation of the project, intentions and method of data collection along with the requirements required from anyone willing to participate. Information on the processing of the data collected will also be provided. Anyone who would be willing to take part will be accepted.

Age

18 - 70

Personal data for sample 1

- Name (also by signature / consent)

How do you collect data from sample 1?

Field experiment / field intervention

Basis for processing ordinary categories of personal data

Consent (art. 6 no. 1 letter a)

Selection Information 1

Do you inform the committee about the processing of the information?

Yes

How?

Written information (paper or electronic)

Third parties

Are you going to process personal information about third parties?

no

Documentation

How are the consents documented?

- Manual (paper)

How can the consent be withdrawn?

Verbally, electronic means (email, text), written.

How can the data subjects gain access to, correct or delete information about themselves?

The only personal date held will be on the consent form. This will be available upon request at any time.

Total number registered in the project

1-99

Permits

Do you need to obtain the following approvals or permits for the project?

Treatment

Where is the information processed?

- Hardware belonging to the institution responsible for processing

Who processes / has access to the information?

- Student (student project)
- Project manager

Is the information available outside the EU / EEA to a third state or international organization?

no

Safety

Is the personal data stored separately from other data (connection key)?

Yes

What technical and physical measures secure the personal data?

- The information is anonymised continuously

Duration

Project period

01.03.2022 - 31.07.2022

Should data with personal information be stored beyond the project period?

No, data will be stored without personal information (anonymization)

What anonymisation measures will be taken?

- Personally identifiable information is removed, rewritten or roughly categorized

Will the registered be able to be identified (directly or indirectly) in the thesis / dissertation / other publications from the project?

no

Additional information

Appendix 5

Participant information and consent form.

Are you interested in taking part in a research project?

"Comparison of hands-off time in manual and mechanical cardiopulmonary resuscitation during helicopter winching"

T*his is an inquiry about participation in a research project where the main purpose is to compare the hands off chest time during manual and mechanical delivery of chest compressions whilst winching into a helicopter. In this letter we will give you information about the purpose of the project and what your participation will involve***.**

Purpose of the project

The purpose of this project it to ascertain the hands off chest fraction time as a percentage of total winching time when chest compressions are delivered manually and with a mechanical chest compression device. As a secondary outcome the quality of chest compressions delivered manually and mechanically, whilst winching, will be investigated by looking at the depth of compressions.

The scope of the project is to ascertain if mechanical chest compression devices would be beneficial to both patients and winch paramedics working on Search and Rescue (SAR) Coastguard helicopters in the UK.

This is a Masters thesis project.

Who is responsible for the research project?

The University of Stavanger, Norway is the institution responsible for the project.

Why are you being asked to participate?

Since the outcome of this research could impact paramedics working for the UK coastguard, winch paramedics have been invited to participate in this project. The sample has been selected via invitation through their work email account and anyone who is willing to, will be involved.

I have gained consent to contact you from the UK SAR director, UK SAR medical manager and the UK SAR Advanced Paramedic (South).

What does participation involve for you?

- If you choose to take part in the project, you will be required to conduct a number of winching serials. These will involve a stretcher and a mannequin. The mannequin will have Zoll pads and pressure puck in place, which will be attached to the Zoll defibrillator for data collection.
- The first winching evolutions will consist of you performing manual chest compressions (Which you will start as soon and the stretcher is off the ground) whilst being winched into the helicopter. You will continue to deliver compressions until the stretcher is inside the helicopter. The data will be recorded from the puck.
- The second winching evolution will utilise a mechanical chest compression device, which you will activate once the stretcher is off the ground and will stop once the stretcher is inside the helicopter. The data will be recorded from the puck.
- It is anticipated that this will be achieved during the daily, mandatory,1 hour 45 minutes training trip. Where possible, this will be scheduled for a day you are on duty.
- There will be a written consent form that will require you to provide your name. After this no other personal identifiable information will be recorded/required. Your winching data will be stored as either manual or mechanical via the normal means (Bristow medical portal-Zoll). Your name will not be linked to the data at any time.

Participation is voluntary

Participation in the project is voluntary. If you chose to participate, you can withdraw your consent at any time without giving a reason. There will be no negative consequences for you if you chose not to participate or later decide to withdraw. This will not affect your job role and your employer need not know.

Your personal privacy – how we will store and use your personal data

We will only use your personal data for the purpose(s) specified in this information letter. We will process your personal data confidentially and in accordance with data protection legislation (the General Data Protection Regulation and Personal Data Act).

- Abi Wild and Per Kristian Hyldmo will have access to the data for the project. SAR Winch Paramedics will have access to the data downloaded from the Zoll through normal channels. Those not involved in the project will not be privy to information identifying those who are (Unless participants choose to disclose their participation themselves outside of the project).
- To ensure no unauthorised persons are able to access your personal data (Consent forms) they will be filed in a locked drawer at the SAR base until completion of the project after which they will be shredded.
- The data collected will be available on the Zoll data download platform but it will not be possible to link the data to the winch paramedic. This is because the information is not required and therefor will not be documented at any time during the research.

If applicable, indicate:

- Abi Wild will collect and process all data.
- Per Kristian Hyldmo will be the only other person with access to personal data (Consent forms). Bristow employees will have access to the Zoll data through normal channels using their employee log in details. There will be no other institutions involved in this project.
- Participants will not be identified or recognisable in publication. Appreciation that SAR Winch Paramedics in the UK are a specialised minority but their base, date of participation, age, name and background will not be included/identifiable in this project.

What will happen to your personal data at the end of the research project?

The project is scheduled to end 31.06.22. After this time the consent forms will be destroyed and data collected deleted from the data base.

Your rights

So long as you can be identified in the collected data, you have the right to:

- access the personal data that is being processed about you
- request that your personal data is deleted
- request that incorrect personal data about you is corrected/rectified
- receive a copy of your personal data (data portability), and
- send a complaint to the Data Protection Officer or The Norwegian Data Protection Authority regarding the processing of your personal data

What gives us the right to process your personal data?

We will process your personal data based on your consent.

Based on an agreement with Stavanger University, NSD – The Norwegian Centre for Research Data AS has assessed that the processing of personal data in this project is in accordance with data protection legislation.

Where can I find out more?

If you have questions about the project, or want to exercise your rights, contact:
University of Stavanger via Abi Wild (Student) a.wild@stud.uis.no or Per Kristian Hyldmo (Supervisor) per.k.hyldmo@uis.no
Our Data Protection Officer: Rolf Jegervatn

- for Research Data AS, by email: (personverntjenester@nsd.no) or by telephone: +47 55 58 21 17.

Yours sincerely,

Project Leader Abi Wild (Student)

(Researcher/supervisor)

I have received and understood information about the project “Comparison of hands-off time in manual and mechanical cardiopulmonary resuscitation during helicopter winching” and have been given the opportunity to ask questions. I give consent:

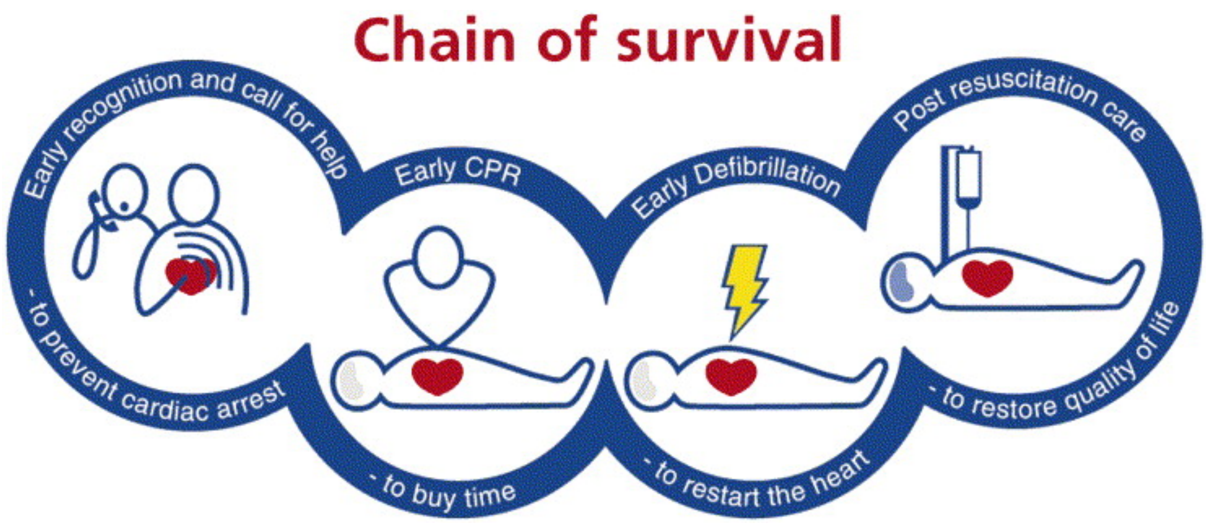
I consent to participate in “Comparison of hands-off time in manual and mechanical cardiopulmonary resuscitation during helicopter winching” ………………………………………………………………..

I give consent for my personal data to be processed until the end date of the project, 30.06.22, approximate.

(Signed by participant, date)

Appendix 6

Sawyer, K. N., Camp-Rogers, T. R., Kotini-Shah, P., Del Rios, M., Gossip, M. R., Moitra, V. K., ... & American Heart Association Emergency Cardiovascular Care Committee; Council on Cardiovascular and Stroke Nursing; Council on Genomic and Precision Medicine; Council on Quality of Care and Outcomes Research; and Stroke Council. (2020). Sudden cardiac arrest survivorship: a scientific statement from the American Heart Association. *Circulation*, *141*(12), p654-685.



Smith, M. (2021). Sudden Cardiac Arrest UK. Cardiac arrest peer support. The *chain of survival.* Retrieved on the 10.09.22 from https://www.suddencardiacarrestuk.org/2021/01/the-chain-of-survival/.

Appendix 7

Standard deviation of manual and mechanical data

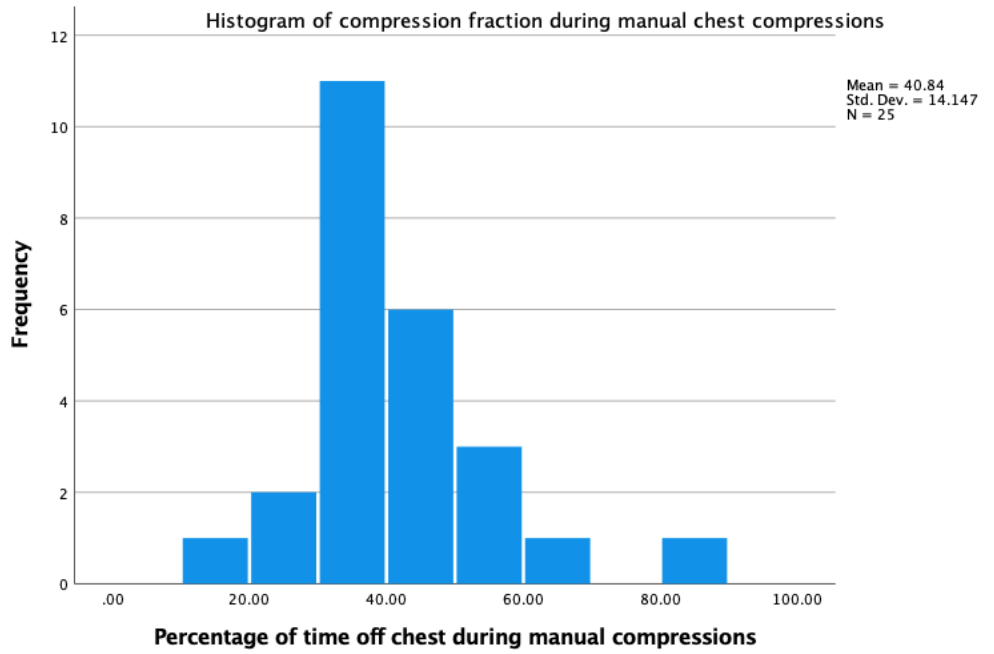
Descriptive Statistics

	N	Minimum	Maximum	Mean	Std. Deviation
Manual	25	17.98	86.73	40.8380	14.14730
Valid N (listwise)	25				

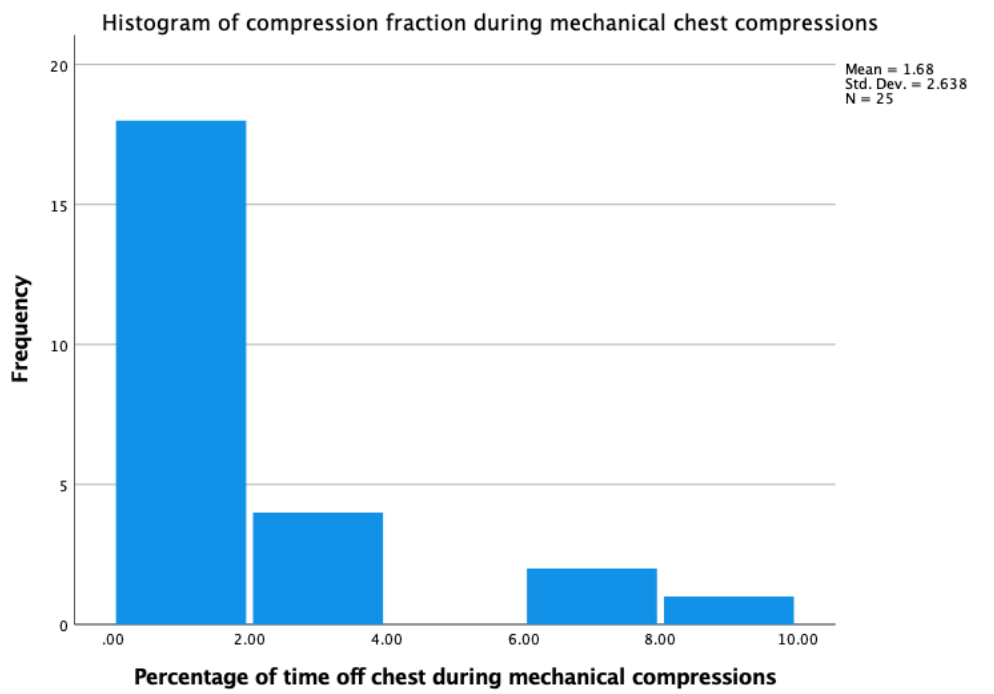
Descriptive Statistics

	N	Minimum	Maximum	Mean	Std. Deviation
Mechanical	25	.00	9.42	1.6764	2.63780
Valid N (listwise)	25				

Appendix 8



Histogram of compression fraction during manual chest compressions
Mean = 40.84
Std. Dev. = 14.147
N = 25
Frequency
0
2
4
6
8
10
12
.00
20.00
40.00
60.00
80.00
100.00
Percentage of time off chest during manual compressions



Histogram of compression fraction during mechanical chest compressions
Mean = 1.68
Std. Dev. = 2.638
N = 25
Frequency
0
5
10
15
20
.00
2.00
4.00
6.00
8.00
10.00
Percentage of time off chest during mechanical compressions

Appendix 9

Secondary outcome

This table shows the data statistics for the compression depth, used in this research to determine the quality of the compressions delivered whilst winching into the helicopter.

Descriptive Statistics

	N	Minimum	Maximum	Mean	Std. Deviation
Mechanical	25	3.90	4.70	4.2240	.20873
Manual	25	3.70	11.10	5.7080	2.22035
Valid N (listwise)	25				