The role of automated compression devices in out-of- and in- hospital cardiac arrest. Can we spare rescuers' hands?

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Abstract

Research regarding the use of mechanical compressions in the setting of a cardiac arrest, either outside of or inside the hospital environment has produced mixed results. The debate whether they can replace manual compressions still remains. The aim of this review is to present current literature contemplating the application of mechanical compressions in both settings, data comparing them to manual compressions as well as current guidelines regarding their implementation in everyday clinical use. Currently, their implementation in the resuscitation protocol seems to benefit the victims of an in-hospital cardiac arrest rather than the victims that sustain a cardiac arrest outside of the hospital.

Introduction

The crucial role of Cardiopulmonary Resuscitation (CPR) in the event of Sudden Cardiac Arrest (SCA) has been undebatable for years. CPR has an indisputable effect on the outcome and prognosis of a patient sustaining a SCA; this is of outmost importance when considering the large pool of patients undergoing either an In-Hospital Cardiac Arrest (IHCA) or an Out-Of-Hospital Cardiac Arrest (OHCA). In the UK approximately 35.000 patients sustain an IHCA every year.[1] Data regarding OHCA suggest that its prevalence is very high both in Europe and in the USA.[2] Return Of Spontaneous Circulation (ROSC) is a crucial indicator of the effectiveness of the interventions made when treating a SCA. However, in a setting of OHCA even though one third of patients achieve ROSC when treated, survival rate is only 8%.[3] Also, even though almost half of IHCA adult victims achieve ROSC initially, long-term survival is also poor.[4]

Effective Chest Compressions (CCs) are the cornerstone of high-quality CPR. Optimal CCs are characterized by a proper rate and adequate depth, minimal interruptions and full chest recoil.[5] However, in a resuscitation setting the delivery of optimal CCs can be highly demanding for the rescuer, their quality being disproportional to operator exhaustion. In a study of manual CCs, over 80% of rescuers experienced serious back discomfort, mostly related to the duration of CPR and a significant 20% suffered back injury or prolapsed disc.[6]

Also special considerations on the quality of CCs have to be taken into account when SCA happens in non-friendly settings, such as inside the moving ambulance, the cardiac CT suite or even the cardiac catheterization laboratory; in the latter, the extreme danger by the ionizing radiation to the person providing CCs must be taken seriously into account. In an attempt to resolve this issue, Automated Chest Compression Devices (ACCDs) have been implemented in the resuscitation process. ACCDs deliver constantly high level compressions, of consistent rate and depth over even prolonged periods of time; as a side note, they run on batteries and can last up to one hour when disconnected from power supply.[7,8] There are two mechanism types of ACCDs, based on the compressions delivery mode: (i) the one using a Piston-Driven technique (PD) (Lucas, Life-Stat, Weil) – (mostly well-known and used is the Lucas device – Figure 1 – Stryker Corp., Sweden), thus applying antero-posterior energy on the sternum; (ii) the other uses a Load-Distribution Band (LDB) (Autopulse – Figure 2 – ZOLL Medical

Corp., USA) which distributes the force applied on the torso more evenly.[9] Studies have compared manual CCs and ACCDs in both OHCA and in IHCA. In this review, we attempt to present up to date literature regarding their role in cardiac arrest, application in clinical practice and current guidelines.

Application in IHCA

Extracorporeal Membrane Oxygenation (ECMO), mainly percutaneous veno-arterial ECMO, and left ventricular assist devices as means of advanced CPR in the hospital setting have been proved to have favourable outcomes; however they are considerably invasive, very expensive and therefore are not widely or universally used. The major concern during CPR is the delivery of uninterrupted CCs, as well as the effectiveness of the resuscitation team in performing all interventions needed for a successful outcome. A further concern in places like the catheterization laboratory is the extensive exposure of the staff performing CCs in the detrimental effects of ionizing radiation.

Mechanical devices can provide a suitable solution to all these challenges.[10] Research so far has been mainly focused on the use of ACCDs in the pre-hospital setting. Their use in the IHCA setting has not been studied as thoroughly, despite of the fact that it engulfs advantages that otherwise lack. More specifically, in IHCA contrary to OHCA, the devices are deployed more quickly and

effectively during the arrest. In addition, although most of cardiac arrests occur outside of the hospital environment, hospital stuff is more frequently exposed to cardiac arrest cases thus having developed greater experience.[1] A systematic ACCD review including trials, case reports and case series reported, with the exception of two studies, a survival rate of 39%, and of those who survived, a full neurological recovery in 91%.[11] Both types of ACCDs where used (piston and band). Those results were attributed to the early initiation of mechanical CCs along with uninterrupted and consistent delivery of high-quality compressions, especially in patients with a reversible cause of cardiac arrest.[11] Similarly, a meta-analysis of nine studies (of which three were randomised), including both types of devices, reported improved hospital and 30-day survival rates with the use of ACCDs. Regarding short-term survival, reports suggested good outcomes with the use of ACCDs. However, there were limitations, including lack of reports regarding neurological outcomes and CPR quality. The risk of bias in the observational studies and the indirectness of evidence were also highlighted.[1] Patient safety was also examined; rib fractures, a sternal fracture and one liver laceration were reported in two of the studies analysed, with no report of which device used in each case. Injuries, however, were similar between ACCDs and manual CCs.[1] A forensic study identified as an Autopulse pattern of injuries the following: posterior rib fractures, skin abrasions along the antero-lateral chest and shoulder, vertebral fractures, and few visceral injuries.[12] A two-year Autopulse registry for IHCA, reported favourable outcomes, expressed as survival to discharge, when the device was used in cardiac arrest of reversible causes.[13] In the same case-series, however, four different situations leading to Autopulse failure on four different patients where mentioned, including battery depletion, clip detachment, compression band twist and difficult backboard placement. The need of correct placement in order to avoid iatrogenic injuries is strongly highlighted.[13]

Better in-hospital ACCDs outcomes can be attributed not only to specialized staff and better time allocation, but also to the advanced infrastructure of the hospital environment, ranging from airway support including intubation and ventilation during CPR, to acute patient care including drugs, induced hypothermia, catheterization and intensive care unit monitoring post-resuscitation.

Figure 1. The Lucas device (piston-driven device for mechanical chest compressions): a piston pushes downwards the sternum at a constant rate 100 per minute, instead of a human resuscitator.

Figure 2. The Autopulse device (load-distributing band device). A band rhythmically constricts the entire rib cage, pumping the heart at a rate of 80 compressions per minute.

Quality of manual CCs in the hospital pose a challenge, as in-hospital patient mattresses tend to absorb up to 40% of the force produced during compressions.[14] On the other hand, the time pause needed for the deployment of the device is considered a considerable limitation in IHCAs. However, data imply that trained resuscitation teams deploy the devices effectively with a minimum pause in ongoing CPR efforts.[15] The learning curve required for the successful deployment of an ACCD is, however, brought into attention when implementing mechanical CCs into the CPR protocol.[13]

Recently, the design of a trial that randomized victims in a 3:1 ratio (mechanical CPR: manual CPR) was published.[16] It attempted to examine the outcomes of a PD device (Lucas) use during resuscitation of IHCA victims with non-shockable initial rhythms, but ended up rather identifying important limitations regarding an efficient study design that would successfully implement mechanical CPR into the resuscitation protocol. More specifically, hospital survival was lower than anticipated, possibly due to late intra-arrest randomization, non-superior CC quality in the Lucas arm and low overall recruitment; the authors highlight the feasibility of such a successful trial design only when all limitations and challenges will be taken into consideration.[16] Cardiac arrest in an emergency department setting, although typically classified as an IHCA entity, comprises mainly of OHCA patients, thus tending to be a separate entity. Therefore it is categorized in trials as such.[17,18]

Application in the cardiac catheterization laboratory

Historic data of more than 20 years ago stated that approximately 1.3% of all patients undergoing cardiac catheterization sustained a cardiac arrest.[19] In the modern era, despite complex percutaneous coronary and structural interventions (PCI, TAVI etc), improved techniques and equipment led to a fall in SCA prevalence.[20] ROSC is often achieved fast, due to early defibrillation and prompt initiation of CPR by experienced nursing and medical cathlab personnel. However, prolonged CPR may be required; in this case fluoroscopy equipment and table height may pose challenges in manual CCs application.[20-23] Furthermore, exposure of the staff to high doses of ionizing radiation during CPR in the catheterization laboratory is a major concern, as high doses of radiation accumulated over time have been associated with malignancies, skin reactions, cataract, bone injuries and heritable effects in the descendants.[21] Thus, protection against uncontrolled exposure to radiation has been established through radiation safety program that implements radiation monitoring, protective shields, training of personnel and modernized fluoroscopy equipment.[22] The use of ACCDs has been studied and case reports, citing the use of the Lucas device, have highlighted its advantages; the most prominent is the lack of need for additional staff for compressions and the ability of ongoing life-saving interventions (for example primary percutaneous coronary intervention in STEMIs) along with the effective, uninterrupted use of the device which is translucent and can even continue compressions with extremely minimal pause for defibrillation.[24-27] With the Lucas device, all views except for straight antero-posterior are applicable during cardiac catheterization, and the device permits free movement of the X-ray detector.[28] The force delivered does not affect the catheterization itself, although minor interruptions for coronary stent deployment may be needed.[28] On the other hand, the delay of the initial deployment has been reported as a drawback. However, with training, this time can be reduced to a median of seven seconds.[9] Data so far have contemplated the use of an ACCD during PCI, in most cases with the Lucas device, and suggested improved ROSC rates along with better survival rate and neurological outcomes at hospital dis-

charge compared to manual CCs.[29] Furthermore, a study further supported the improved ROSC rate even in patients that were brought to the laboratory with ongoing ACCDs compressions.[23] Mechanical compression devices can bridge patients in cardiac arrest to deployment of a fully percutaneous mechanical circulatory support in the cathlab. However, survival to hospital discharge was similar to manual mechanical CCs.[23] In a case series, use of the Lucas device was found to be beneficial for patients that sustained cardiac arrest during catheterization, especially during PCI,[28] a finding attributed to the vital blood pressure levels the device can effectively maintain.[26] Use of band distributor ACCDs (Autopulse) has also been reported, also allowing interventions in the cathlab and providing uninterrupted compressions during PCI.[30,31] Continuous effective CPR in a sterile field along with unobstructed visualization of the coronary arteries during catheterization were therefore observed with the use of Autopulse in the cathlab.[13] Based on the above, the American Heart Association in its 2010 Guidelines for Cardiopulmonary Resuscitation[32] stated that mechanical piston or load-distributing band chest compression devices may be considered in patients undergoing PCI or CT scans, for prolonged resuscitation (class IIa) or when manual resuscitation is difficult (class IIb). It is mandatory that trained personnel implement the use of such devices. However, up to this point, there is insufficient evidence to support or refute their routine use in cardiac arrest. The European Resuscitation Council (ERC) supported and co-authored the 2010 guidelines[32] and in the recent 2015 guidelines once again strongly recommended the use of ACCDs in the cathlab during coronary interventions.[33]

Application in OHCA

Data regarding ACCD use in a setting of OHCA are more extensive than IHCA. Although animal models have suggested favourable outcomes with mechanical CPR,[34,35] real-life application on cardiac arrest patients has produced mixed results. An early randomized trial concluded that the use of a load-distributing band is associated with worse neurological outcomes as well as worse 4-hour survival, compared to manual CCs.[36] Long pause for its application has been noted with a piston device, a finding that could possibly explain its unfavourable outcomes.[37] On the other hand, a more recent meta-analysis, that examined both types of devices in an OHCA setting regarding ROSC in a total of twelve studies, showed that mechanical CPR benefits outcome, with the condition that the staff applying it is sufficiently trained.[38] Minimal interruptions of compressions achieved through the ACCD allows rescuers to perform other activities, crucial to patient survival. Interestingly, in this meta-analysis load-distribution devices outperformed piston-driven devices, while piston-driven devices exhibited similar ROSC rates to manual CCs.[38] Thirty-day survival, survival to hospital admission or survival to discharge were comparable between manual CCs and the Lucas device in another meta-analysis, although manual CPR proved superior to Autopulse; in terms of patient safety, manual CCs were superior to the devices.[39] The use of ACCDs in OHCA has been categorized in three different subsections, depending on the setting in which the resuscitation is taking place.

Use in the Emergency Room

SCA cases treated within emergency departments around the world are cases of OHCA as well as patients that suffer cardiac arrest while waiting in the emergency room (ER).[17] A randomized trial examined the effect of trained personnel using an LDB device

protocol in the ER and concluded that it provides better CPR quality to the patient, with shorter interruption during deployment of the device.[15] Similarly, the use of the Autopulse device in two ERs in Singapore revealed an association between mechanical CPR period and ROSC rates after adjusted analyses, but no association with other outcomes.[40] On the other hand, a randomized trial executed in Japan showed that the arm that was treated for OHCA with a device in the ER had worse survival rates to hospital discharge along with worse admission to hospital survival and decreased likelihood of ROSC, possibly due to deployment pauses in CCs and lack of mechanical CPR quality feedback.[41] Differences in findings among studies may be attributed to different protocols, different study populations or risk of bias.[17]

Use during transfer to hospital

Worldwide, SCA patients are more and more often transferred to the hospital with ongoing CPR, unfortunately of doubtful quality.[42,43] Patients may arrest during transport or OHCA patients may need transportation.[44,45] Manual compressions during transfer to the ED have been proved to be both ineffective for high-quality CPR and unsafe for emergency medical service (EMS) staff.[46] Various difficulties - including but not limited to - uneven pavements and tight doorways during transfer of the victim to the ambulance, sudden stops, accelerations, turns and confined ambulance space, adversely affect CPR quality.[44] Mechanical compressions exhibit advantages, such as non-stop continuousness of compressions, while all EMS staff is seated during transportation.[38] Furthermore, an observational study found that ACCDs minimize compression interruptions that occur with manual CPR during extrication of a patient, except for the deployment pause.[47] In a case-control study, higher rates of ROSC were reported in the mechanical CPR arm.[48] Same results were reported in an observational study, that confirmed higher ROSC rates and survival to hospital admission when a device was implemented in CPR during transportation.[49] In a review on OHCA patients that received mechanical CPR during transfer to the hospital revealed better CPR quality for mechanical CPR regarding rate, compression ratio and depth, irrespective to vehicle type and transportation conditions.[44] Both types of devices were examined. However, in regard to survival and outcomes, the heterogeneity of the included trials challenged the generalization of the results. Consequently, it appeared that mechanical and manual CPR may have similar outcomes; however, the importance of high-quality CPR and proper personnel training in both cases is highlighted throughout.[44,50]

Mechanical compression devices can be available in ambulances to support victims of OHCA during transportation, in case cardiac arrest re-occurs. This is especially the case when a long distance needs to be covered. The Danish cardiac arrest registry (41.186 OHCA patients in Denmark, during 2001-2013),[50] showed a marked reduction in mortality when resuscitated out-of-hospital arrest victims were transferred to coronary angiography capable tertiary hospitals versus transfer to the nearest district hospital (odds ratio 0.78, with 95% confidence interval 0.76–0.81) and especially when they underwent emergency PCI or coronary bypass surgery. This favorable effect of the so-called "invasive" hospitals persisted, irrespective of the distance the resuscitated victim had to travel by ambulance (odds ratio 0.93, 0.97, 0.98, 0.99 and 1.01 for transfers of 0–5, 5–10, 10–20, 20–50 and 50–100 kilometers compared to 101-200 kilometers, respectively).[50]

Routine deployment on scene

In a large proportion of OHCA, CPR in general and chest compressions in particular are initiated by bystanders.[2] Data from

European registries report a variable percentage of ROSC, depending on first rhythm, witnessed SCA, ongoing CPR and differences in EMS systems.[2,3] In a randomized study examining effects of mechanical compressions by a PD device in OHCA, no difference was noted in early survival between device and manual CCs.[51] The pause of compressions during manual CPR needed to deliver a defibrillation shock has been proved to be an independent predictor of survival in OHCA.[52] ACDDs can offer continuous high-quality compressions, with full chest recoil, on the scene of cardiac arrest, while defibrillation can take place simultaneously.[38] However, in the randomized ASPIRE trial the deployment of the load-distribution device costs a delay of 2.1 minutes to first shock in ventricular fibrillation; due to neurological and survival adverse outcomes the trial was prematurely terminated.[36] Prolongation of time to first shock was prominent in CIRC and LINC trials as well.[53,54] Rescuers were trained, in an attempt to minimize interruptions in both those studies. Furthermore, cost-effectiveness does not favor the routine use of mechanical CPR in OHCA.[55] Factors such as body weight and applicability of the device have also been highlighted, as not all patients can receive properly a device; thus, further prolongation of application may occur.[54] Last, patient safety is not yet fully clarified, as very few studies have addressed the issue.[56] In this randomized trial, liver lacerations associated with massive hemorrhage were reported in two patients in the Lucas arm along with one Autopulse-associated tension pneumothorax that caused an air embolus; manual CC-associated hazards were fewer.[56] Pre-hospital use of ACDDs has been shown to offer worse neurological outcomes to hospital discharge when compared to manual CPR.[57,58] The LINC trail randomized on the scene SCA victims into manual compression versus Lucas-mediated compressions. Primary outcome was four-hour survival after ROSC. The results of the trial revealed no differences in neither four-hour survival between the two arms, nor the six-month survival and neurological outcomes. Although defibrillation took place in all victims during compressions irrespective of initial rhythm, in the Lucas arm first defibrillation shock occurred 1.5 minutes later. The device well-suited 95% of the patients.[54] The effects of on-scene Lucas deployment were examined by the PARAMEDIC trial as well. This was a 2:1 randomized trial (manual:Lucas) that presented its results as part of a meta-analysis, alongside two other studies. In the primary outcome of thirty-day survival, no superiority of the device was proven.[59] In the randomized CIRC trial a LDB device versus manual CPR was examined. Survival to hospital discharge was examined as the primary outcome, while CPR quality was throughout measured. The two arms of the study displayed similar survival rates and neurological outcomes to hospital discharge. However, the manual arm received controlled and optimal CPR, although this may not be always the case in a real-life OHCA scenario.[53] Serious adverse events were similar between the LINC and CINC trials. The heterogeneity of trials conducted for comparison of techniques poses a challenge when techniques are being compared. ACCDs have been proposed to improve pre-hospital and admission to hospital survival especially when used by a two member paramedic team, when the victim is young in age and when the arrest takes place in the town center.[8] A 2019 meta analysis did not support the use of LUCAS in OHCA settings regarding clinical outcomes compared with manual chest compression.[60]

Current guidelines and the COVID-19 era

Routine use of ACCDs is not recommended according to cur-

rent guidelines.[32,61] However, in special cases, such as during transportation or catheterization, during prolonged CPR or CPR taking place in a confined space, their use is advised.[61-63] Furthermore, consensus documents along with guidelines support their use during PCI or CT (class IIa).[20,64] As aforementioned, the American Heart Association, in its 2010 Guidelines for Cardiopulmonary Resuscitation,[32] classified the use of ACCDs for prolonged resuscitation as class IIa in patients undergoing PCI or CT scans. In the case of difficult manual resuscitation, their use was categorized as class IIb. Only trained personnel must handle the devices. Up to that point, they stated that there was insufficient evidence to either support or refute their routine use in cardiac arrest. ERC co-authored the 2010 guidelines[32] and later strongly recommended the use of ACCDs in the cathlab during coronary interventions in its 2015 guidelines.[33]

The need for minimal interruptions is highlighted, restricted only to the initial deployment of the device. In an ambulance staffed by two paramedics, a mechanical device can be proven useful, although guidelines do not fully support it.[65]

The use of mechanical CPR in special settings has been studied as well. It has been used as a bridge to uncontrolled organ donation.[66,67] Although ethical and clinical challenges are raised, the use of mechanical CPR can reduce the time of warm ischemia,[68] vital in a setting of uncontrolled organ harvest.[17] In another setting, during insertion of extracorporeal CPR (cardiopulmonary bypass) the use of an ACCD may be proven useful and it is applied with positive results, although data are still limited.[69-71] It is of outmost importance that the ethical dilemmas and clinical decisions made in a case of refractory SCA require very careful consideration.[17,72]

During the SARS-Cov2 virus pandemic (COVID-19), new questions arose regarding CPR and new protocols were implemented in patient management. Modifications were installed by the ERC[73] and also by various national societies[74] in the proposed CPR process (basic and advanced life support algorithm) to protect rescuers from cross-infection. In a setting of OHCA, a piece of cloth is placed on the victim's face before the initiation of CPR while the rescuer is advised to wear a mask and wash his/her hands immediately after. In the case of IHCA, the advanced life support algorithm is followed with extreme caution to personal protective equipment, airway management and compressions. The use of ACCDs is advised, as soon as the device is available.[74,75]

Conclusions

Data regarding the use of mechanical CPR in cases of both out-of- and in-hospital cardiac arrest are mixed. In general, the use of devices in OHCA situations seems to show weak and conflicting evidence on the outcomes of the victims, while in IHCA it has a rather positive impact. High-quality CPR remains the key to a successful resuscitation and as such its importance is highlighted in all studies comparing manual and mechanical CPR. Large registries and randomized trials should further elucidate this debate, CPR quality measurement being a key component in their design.

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