

# World Journal of *Cardiology*

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## Cardiac arrest and cardiopulmonary resuscitation in “hostile” environments: Using automated compression devices to minimize the rescuers’ danger

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## Abstract

Mechanical automated compression devices are being used in cardiopulmonary resuscitation instead of manual, “hands-on”, rescuer-delivered chest compressions. The -theoretical- advantages include high-quality non-stop compressions, thus freeing the rescuer performing the compressions and additionally the ability of the rescuer to stand reasonably away from a potentially “hazardous” victim, or from hazardous and/or difficult resuscitation conditions. Such circumstances involve cardiopulmonary resuscitation (CPR) in the Cardiac Catheterization Laboratory, especially directly under the fluoroscopy panel, where radiation is well known to cause detrimental effects to the rescuer, and CPR during/after land or air transportation of cardiac arrest victims. Lastly, CPR in a coronavirus disease 2019 patient/ward, where the danger of contamination and further serious illness of the health provider is very existent. The scope of this review is to review and present literature and current guidelines regarding the use of mechanical compressions in these “hostile” and dangerous settings, while comparing them to manual compressions.

**Key Words:** Automated compression devices; Cardiopulmonary resuscitation; Cathlab; Computed tomography; Transfer; COVID-19

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**Core Tip:** The use of automated compression devices in ‘hostile’ environments, both in in- and out-of-hospital cases of cardiac arrest, seems to be beneficial both regarding compressions’ quality but especially the rescuers’ safety. So far, while experimental data is extensive, real-life studies examining their use in non-friendly situations are still limited. Since high-quality cardiopulmonary resuscitation remains the key to a successful resuscitation, their use such difficult and “hostile” situations should be seriously taken into consideration. Noteworthy, such a use is indeed implied by guidelines.

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## INTRODUCTION

Cardiopulmonary resuscitation (CPR) is the pillar of cardiac arrest treatment. High numbers of people sustain cardiac arrest both inside and outside of the hospital every year[1] thus, making the need for high-quality CPR crucial, in order to save human lives.

The cornerstone of high-quality CPR is effective chest compressions (CC). The characteristics of great-quality CCs are proper rate, adequate depth, full chest recoil, and minimal interruptions[2]. However, during the highly demanding resuscitation setting optimal quality of CCs is not always achieved. Rescuer exhaustion is the main reason for suboptimal CCs, as compressions are extremely demanding and tiring for the providing rescuer. In a study of manual compressions, the vast majority of rescuers reported serious back discomfort, mostly related to the duration of CPR, while approximately 20% of the rescuers suffered back injury or reported a prolapsed-disk diagnosis[3].

Besides operator exhaustion, hostile settings related to cardiac arrest are often the reason for CCs of suboptimal quality. Those settings include but are not limited to, resuscitation in a moving ambulance during patient transportation, inside the computed tomography (CT) scanner, or in the cardiac Catheterization Laboratory (CathLab). Especially for the CathLab, it is not only difficult for the operator to perform high-quality CCs due to the existence of the equipment, but it is also very dangerous, due to the hazardous ionizing radiation.

Mechanical automated chest compression devices (ACDs) implement all the necessary qualifications to solve all the aforementioned problems and have been implemented in clinical practice. Many studies, reviews, and meta-analyses have contemplated the use of ACDs in the clinical setting of a cardiac arrest, presenting both the upsides of their use and the potential obstacles. ACDs can deliver high-quality compressions, of consistent rate and depth, lasting up to one hour when disconnected from their energy source[4,5].



There are mainly two device types of ACDs, based on the compressions' delivery style (Figure 1). The first type is piston-driven (PD) (Lucas® Stryker Medical, United States, Life-Stat® Michigan Instruments, United States) –thus applying anteroposterior thrust on the sternum. A recent study showed that the use of a piston-driven ACD (which uses a suction cup) is associated with higher coronary perfusion pressure[6]. The second type of ACD uses a load-distribution band (LDB) (Autopulse® Zoll Medical Corp, United States) and distributes the force applied to the patients' torso more evenly[7]. Both types have been studied in the settings of both the in-hospital cardiac arrest (IHCA) and the out-of-hospital cardiac arrest (OHCA) and they seem to be more beneficial in the setting of IHCA[7]. A novel idea, however, is that they can be of great value in a 'non-friendly' setting of a cardiac arrest, either IHCA or OHCA. In this review, we present current data and literature regarding the implementation of ACDs in cardiac arrest in a 'hostile' environment.

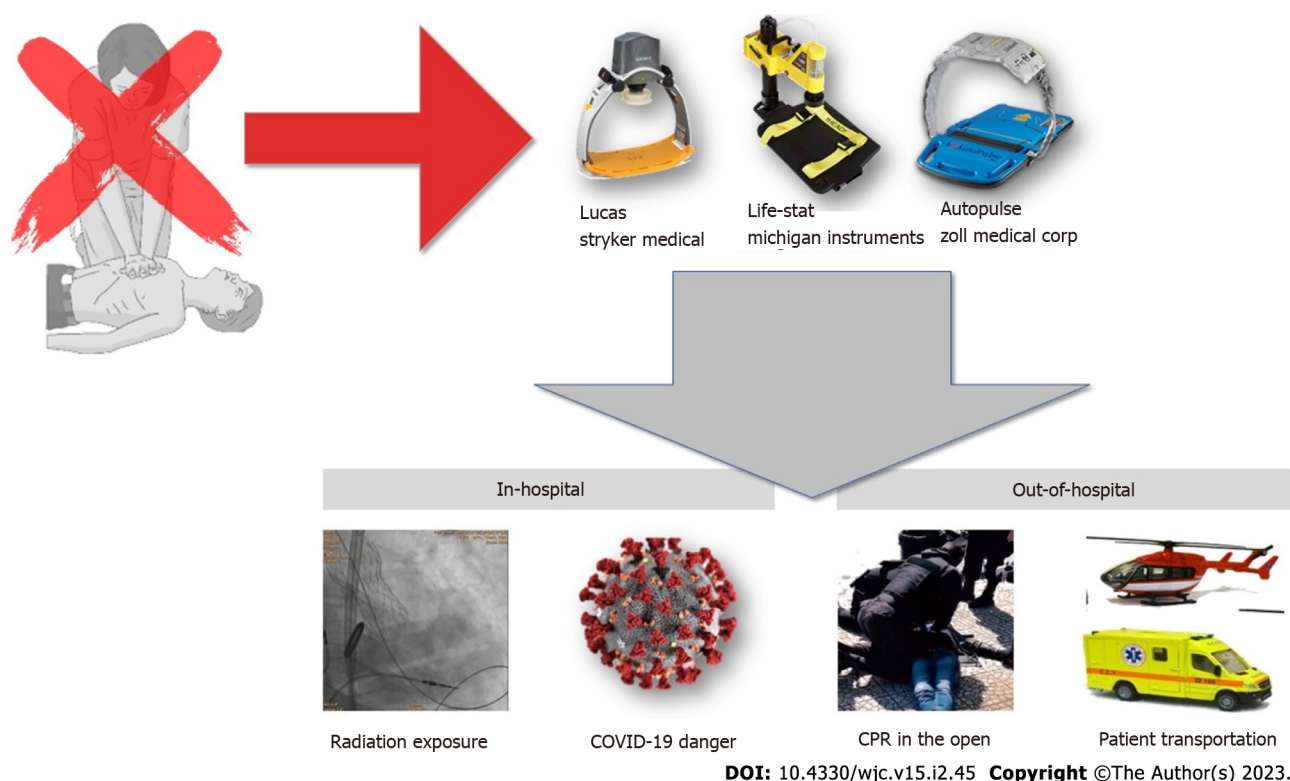
## IN-HOSPITAL CARDIAC ARREST

The use of ACDs in the hospital environment (Figure 1) combines various advantages. The devices can be deployed fast, and they solve the problem of energy loss, as the in-hospital hospital-bed mattresses tend to absorb up to 40% of the force produced during chest compressions[8]. They are easier to use and considerably less invasive than the Extracorporeal Membrane Oxygenation that is used in cardiac arrest settings, and they additionally require easier training[9]. Furthermore, the infrastructure of the hospital environment is highly advanced, offering high-quality post-resuscitation care, a well-trained resuscitation team, very efficient airway management, and minimized response times; thus, in-hospital setting CPR, assisted by ACDs, can offer a superior, more organized peri-arrest care to patients. So far, data indicated that the use of ACDs in the IHCA setting can be beneficial when compared to manual cardiac compressions, although further data could elucidate more on the standing debate[7].

However, although the ACDs can offer a sustainable solution to the very important constant-high-quality-compressions problem, they can pose limitations. Patient safety has been studied, and patient injuries (such as rib fractures, liver lacerations, or vertebral body fractures) have sporadically been reported[9]. Furthermore, device failure has also been reported[10,11]. A learning curve required for the correct use and placement of the devices, with minimum interruptions of the ongoing manual compressions, has also been brought to attention[10]. The randomized COMPRESS-RCT study[12], although prematurely terminated due to unfavorable outcomes in the use of a certain ACD type (Lucas) in the hospital environment, did accentuate important aspects and limitations regarding the implementation of efficient ACD-study protocols. Hospital survival was low, while the identified problems were delays in the intra-arrest randomization, non-superior compressions quality in the Lucas arm, and low overall recruitment[12].

### *In-hospital 'hostile' environment*

**Radiation exposure:** Despite the limitations arising from using ACDs in the hospital environment, data suggest that their use in special settings and non-friendly situations is beneficial and even suggested. More specifically, although improved techniques, equipment, and training led to a fall in cardiac arrest cases in the cardiac cath lab[13], prolonged CPR may still be required[13]. The presence of the equipment as well as the ionizing radiation constitute a 'hostile' environment. Radiation exposure during manual CCs is a major concern, as accumulated doses over time have been associated with multiple health hazards[14]. As a result, the protection of the rescuers from radiation should be a priority. The use of ACDs in the CathLab can substitute manual compressions, thus eliminating the need for extra personnel during the resuscitation process. Furthermore, ACDs can offer good-quality compressions during the ongoing catheterization process (*i.e.* primary PCI), as they are greatly translucent[15]. The Lucas device has been reported to allow free movement of the radiation detector and allow all views during catheterization, except for the straight anteroposterior[16]. The device compressions do not affect the interventions during catheterization, although minor interruptions for coronary stenting may be warranted[16]. Although the initial device deployment delay has been reported as a drawback, the time needed can be reduced to a median of seven seconds with proper staff training[17]. So far, the Lucas device has been mainly studied in the CathLab in the form of case reports. During PCI arrest, it has been shown that the device, when compared to manual CCs, has better outcomes in terms of both return of spontaneous circulation (ROSC) and survival rates at hospital discharge[18]. The blood pressure levels that the device can maintain during resuscitation are also of vital importance[19]. The device can also assist the resuscitation process as it can be used during the transportation of the patient to the cath lab. A study contemplated that better ROSC rates are achieved for patients transferred to the CathLab with ongoing mechanical compressions[20]. In the event of PCI, a Lucas case series argued that the device was beneficial for patients[16]; Autopulse case reports also argue that uninterrupted visualization during catheterization is achieved thus allowing all interventions [21,22]. On the other hand, a study stated that ongoing CPR upon arrival at the CathLab and continuous mechanical compressions for over 10-20 min in the CathLab were both predictive of poor outcomes[23]. Of interest, a recent study revealed that for patients undergoing PCI under mechanical compressions,



**Figure 1 Automated compression devices instead of hands-on manual cardiopulmonary resuscitation to minimize the rescuers' danger in in-hospital and out-of-hospital cardiac arrest resuscitation.** COVID-19: Coronavirus disease 2019; CPR: Cardiopulmonary resuscitation.

mild hyperkalemia might be beneficial, identifying the potassium (KCl) concentration of 5.1 mmol/L to be the optimal cut-off, for the prediction of survival to hospital discharge[24].

The topic of ACD compressions inside the CT scanner has not been studied as extensively. So far, a case report of a pulmonary embolism that sustained cardiac arrest suggested that contrast-enhanced CT imaging with ongoing chest compressions is feasible after cardiac arrest[25]. Experimental data suggest that an ECG-triggered protocol allows almost artifact-free chest evaluation during mechanical compressions[26].

**Coronavirus disease 2019 danger:** CPR is a complex intervention, requiring extensive skills from quite a few knowledgeable healthcare providers. The risks of viral transmission through aerosol and droplet generation during CPR have not yet been fully identified, but a transmission can be detrimental to these valuable and scarce CPR team members[33]. On the other hand, patients with coronavirus disease 2019 (COVID-19) who require intubation and ventilation have extremely poor survival rates[27-29]. The best way to express this concept has already been written, and we also stand for[30]: This pandemic has changed the risk-benefit balance for CPR: from "there is no harm in trying" to "there is little benefit to the patient and potentially significant harm to staff".

During the severe acute respiratory syndrome coronavirus 2 (SARS-CoV-2) virus pandemic, the advanced life support algorithm must be followed with extreme caution to personal protection, especially regarding personal protective equipment, airway management, and compressions, and an ACD should be used, as soon as the device is available[31-32]. The high contagiousness of the SARS-CoV-2 virus changed significantly every day clinical practice and the CPR process. Occupational exposure of healthcare and other personnel to all airborne transmitted pathogens is not by any means negligible but can be minimized through a high index of suspicion, preparedness, and appropriate protection[33].

Regarding changes and additions to the already existing OHCA protocol, it is suggested that cardiac arrest recognition should be performed by searching for the absence of pulse and normal breathing while completely avoiding listening to or feeling breath sounds, by placing one's ear and cheek near the victim's mouth[31]. A cloth should also be placed on the unconscious victim's mouth during the resuscitation process. CPR should be performed only through chest compressions and quick and effective use of an AED is of vital importance without any additive risk to the resuscitation process. Hand sanitizing is an efficient alternative to soap-based hand washing, which is advised immediately after the process[31,34].

Regarding the IHCA CPR process, advanced airway management is mainly endotracheal intubation should be performed by the most trained and experienced physician, as the risk of cross-infection is high. The use of PPE is highly advised in the hospital setting, while participants in the CPR process

should be trained on how to correctly handle, put on and safely remove all PPE equipment[31,34]. As the need for protection through PPE use may delay CPR initiation for patients with COVID-19, "donning/doffing" training can help minimize those delays. Regarding the algorithm, adjustments have been made to accommodate those newly surfaced needs; no CPR should commence without the use of PPE, and for shockable rhythms, up to three back-to-back shocks are allowed to restore the patient's rhythm. CPR should start only with chest compressions, while defibrillation for all shockable rhythms should be given with only minimal delays[31,32].

A mechanical compression device should be used as soon as it becomes available in any setting that allows their safe and efficient use, especially in the need for prolonged CPR[7,34]. The obvious advantage, besides the ones already discussed earlier, is the need for one less –COVID-19 exposed– person in the CPR team. Furthermore, this at-risk person would be the one the closest for the longest duration, to the SARS-CoV-2 infected victim. Therefore, automated chest compression devices have been proposed to be used during COVID-19 CPR[35,36]. When they are not available it was discussed to reduce the duration of the CPR cycles from two to one minute as the quality of chest compressions can deteriorate fast if the rescuer wears PPE[33,35,36].

## OUT-OF-HOSPITAL CARDIAC ARREST

The ACDs have been studied quite extensively in the setting of an OHCA (Figure). So far the results are mixed, as a study suggested that a load distribution band presents worse neurological outcomes and worse survival when compared to manual CCs; however, a meta-analysis concluded that ACDs are associated with better ROSC outcomes, provided that the staff applying them is sufficiently trained[37,38]. In the same meta-analysis, load-distribution devices outperformed piston-driven devices, a finding that may be associated with the necessary pause for application[38,39]. Interestingly, in another meta-analysis of survival to thirty days, it was found that survival to hospital admission or survival to discharge was comparable between the two arms (manual CCs and the Lucas device), although manual CPR proved superior to the Autopulse device; regarding patient safety, manual CCs were superior to the devices[7,40].

### *Out-of-hospital 'hostile' environment*

The OHCA setting is at its core the most challenging one. Compressions, of undetermined quality, are most often initiated by bystanders after significant delays. ACDs, brought by the rapid response EMS (emergency medical system *e.g.* ambulances or motorcycles) can offer continuous high-quality compressions, on the scene of a cardiac arrest, while defibrillation can take place simultaneously; in this way, quality is maintained at a high standard and the need for pauses is minimized[38]. However, in the randomized ASPIRE trial the deployment of the load-distribution device created a delay of 2.1 min to the first shock in ventricular fibrillation. As a result, the trial was prematurely terminated due to neurological and survival adverse outcomes[37]. In another randomized trial no difference regarding early survival between the manual and the mechanical arm was noted[41]. Prolongation of time to first shock was also prominent in CIRC and LINC trials[42,43]. Applicability factors, such as body weight, have also been highlighted and they may also cause delays[42,43]. In a recent study, the mechanical (Lucas) arm did not show added benefit regarding the ROSC rate, but its use did not lead to a higher risk of traumatic injury. The same study suggested that ACDs may be more useful in cases of delayed ambulance response times, or events happening in remote locations[44]. However, liver lacerations, occasionally associated with massive post-resuscitation hemorrhage, have been twice reported in the Lucas arm along with one Autopulse-associated tension pneumothorax that caused an air embolus[45]. The pre-hospital use of ACDs has been associated with worse neurological outcomes to hospital discharge when compared to manual compressions[46,47]. The LINC trial randomized SCA victims into manual compression *vs* Lucas-mediated compressions on the scene and showed no differences in either four-hour survival, six-month survival, or neurological outcomes between the two arms[43]. Similarly, in the PARAMEDIC trial (2:1 randomized trial of manual CCs: Lucas) no superiority of the device was proven in the primary outcome of thirty-day survival[48]. Furthermore, in the randomized CIRC trial (LDB device *vs* manual CPR) the two arms of the study displayed similar survival rates and neurological outcomes to discharge[42]. However, ACDs have been proposed to improve both pre-hospital and admission-to-hospital survival, especially when operated by a two-member paramedic team, the victim is young and the arrest takes place in a city center[5,7].

Cardiac arrests that are treated within Emergency Departments are considered cases of OHCA[49]. Patients that are treated for cardiac arrest in the Emergency Department are in the vast majority, patients that sustained a cardiac arrest outside of the hospital and were transferred with continuous compressions to the ED; thus, the resuscitation process can be quite challenging and may pose difficulties. Research has not definitively concluded regarding the effect of ACDs in ED departments. While a large randomized trial from Japan concluded that the mechanical arm of patients treated in the ED for an OHCA presented worse survival outcomes possibly due to deployment pauses[50], another randomized trial examined the effect of trained personnel operating LDB devices and concluded that



better CPR quality is delivered to the patient, with shorter interruption times during deployment of the device[51].

However, the most challenging setting is during patient transportation. Cardiac arrest patients are sometimes transferred to the hospital with ongoing CPR, of doubtful quality[52] or they may arrest en route to the hospital. Rather conclusive data showed manual compressions during transfer to be ineffective for the patient and unsafe for the providing staff[53]. Various difficulties -including but not limited to uneven pavements and tight spaces and doorways during the victim transfer to the ambulance, sudden stops, accelerations, turns, and confined ambulance space, adversely affect delivered CPR quality[7]. Those are the exact settings in that an ACD may effectively assist the resuscitation process and favorably alter its course. An observational study found that ACDs use, contrary to manual CPR, minimizes compression interruptions during the extrication of a patient, except for the deployment pause[54]. Research has presented beneficial outcomes so far for the use of ACDs of both types during transportation, in terms of higher ROSC, survival to hospital admission, and quantitative CPR quality irrespective of transportation conditions or vehicle type[55,56]. However, regarding survival and outcomes, the heterogeneity of the included trials still poses a significant challenge to the generalization of the results. In every case, the vast majority of studies highlight the need for proper personnel training. The Danish cardiac arrest registry reported a marked reduction in mortality, when resuscitated OHCA victims were transferred to CathLab-capable tertiary centers rather than when being transferred to the nearest district hospital, irrespective of the overall distance the resuscitated victim had to travel by ambulance[57]. During the resuscitation process, an OHCA victim may need to undergo a large distance transportation by ambulance. ACDs may facilitate the process, thus having a place in the resuscitation process during transportation. Experimental data, using manikins, has concluded that the Lucas-2 device, in use by experienced hands, is a good alternative to manual compressions during a rescue-helicopter transfer and it complies -as a system- with all European Resuscitation Council (ERC) recommendations[58]. A randomized study, also using manikins, concluded that the Lucas system increased CPR quality and reduced pauses during helicopter rescue, but prolonged the time interval to first defibrillation[59]. Similarly, regarding transportation down stairwells and through tight spaces, experimental data proposing a new Lucas-2 system with shoulder strap fixation during non-supine stretcher transportation, allowed uninterrupted compressions, while yielding better chest compression fractions for the overall resuscitation period[60]. A randomized triple cross-over experimental study in an alpine setting revealed that Corpuls and Lucas-3 maintained the adequate quality of CPR during transportation and the piston was placed correctly even during challenging terrestrial transport[61]. Furthermore, a manikin-based study contemplated that while ambulance speed can affect manual compressions quality during transportation, devices of both types can resolve quality issues[62]. A similar experimental study showed good device performance during transport on a soft stretcher or gurney involving a stairwell, trips with a turntable ladder, a rescue basket, and an ambulance including loading/unloading of the patient, but underlined the need to check patient-device connection and stability[63]. All experimental studies highlight the need for real-world data. A retrospective observational study in Switzerland concluded that the implementation of mechanical compression devices in helicopter transportation can be beneficial, especially for non-trauma patients[64]. However, a recent German registry reported that mechanical devices are not associated with better survival rates when used during transport, but are associated with better survival in prolonged resuscitation. They are, however, associated with worse survival when a fibrinolytic was used; rescuer safety could be a sufficient reason for their use[65].

The use of mechanical compression devices has been used as a bridge to uncontrolled organ donation [66]. Although both ethical and clinical challenges are raised, the use of ACDs can reduce the time of warm ischemia[67]. During the insertion of extracorporeal CPR (cardiopulmonary bypass), the use of an ACD may be useful and it is applied with positive results, although data are still scarce[7]. In the case of refractory cardiac arrest, ethical dilemmas require very careful consideration[68].

## GUIDELINES

Regarding current guidelines for in-hospital practice, the American Heart Association in 2010 stated that piston-driven or load-distributing band chest compression devices may be considered in patients undergoing PCI or CT scanning, for prolonged resuscitation (class IIa) or when manual resuscitation is challenging (class IIb)[69].

The ERC in its 2015 guidelines strongly recommended the use of ACDs in the cath lab during coronary interventions[70]. It is mandatory for trained personnel to implement the use of such devices, but there is insufficient evidence to support or refute their routine use in cardiac arrest[7].

In the latest (post COVID-19 pandemic) 2021 ERC guidelines the use of ACDs is considered if high-quality manual CPR is not practical or is dangerous for the provider[71].

## CONCLUSION

The use of ACDs in 'hostile' environments, both in in- and out-of-hospital cases of cardiac arrest, seems to be beneficial both regarding compressions' quality and especially the rescuers' safety (Figure 1). So far, while experimental data is extensive, real-life studies examining their use in non-friendly situations are still limited. Since high-quality CPR remains the key to successful resuscitation, their use in such difficult and "hostile" situations should be seriously taken into consideration. Noteworthy, such use is indeed implied by guidelines.

## FOOTNOTES

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