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Percutaneous Coronary Intervention During Cardiac Arrest and Ongoing Chest Compressions

Göran K. Olivecrona and Marko Noc

1. Department of Cardiology, Skåne University Hospital-Lund; 2. Centre for Intensive Internal Medicine, University Medical Centre, Slovenia

Abstract

Prolonged cardiac arrest in the cath lab is associated with very high mortality rates. Use of manual chest compressions have, until recently, been the only rapid response available to circulate the patient in such scenarios. The recent introduction of mechanical chest compression devices offers a new alternative that may perform better than manual chest compressions, especially during a continued interventional procedure.

Keywords

Chest compressions, percutaneous coronary intervention (PCI), cardiac arrest, cath lab, cardiopulmonary resuscitation (CPR)

Although approximately 2,000,000 patients undergo PCI yearly worldwide, only a very small minority will suffer a protracted cardiac arrest episode during the procedure that results in death.1 Cardiac arrest itself in the catheterisation laboratory (cath lab) is not an uncommon event, but is usually rapidly resolved with cardiopulmonary resuscitation (CPR) and DC conversions in cases of ventricular fibrillation, especially following reperfusion in patients with acute myocardial infarction during primary percutaneous intervention (PCI).2 A smaller number of patients will suffer an extended period of cardiac arrest, however, and survival among these patients is very low with more or less only anecdotal reports of survival among patients, usually suffering from a lesion in the left main artery or the left anterior descending artery.3–6 During the course of a lengthy resuscitation effort due to cardiac arrest in the cath lab, quick restoration of circulation through advanced cardiac life support is required and is almost universally immediately started with manual chest compressions delivered on the cath lab table. Often the cause of the extended cardiac arrest can easily be identified and a continued uninterrupted PCI procedure of, for example, a suddenly occluded left main artery is often the best option for attaining return of spontaneous circulation (ROSC).7

Before PCI can be attempted, the primary issue will be to maintain cerebral and coronary circulation. Traditionally, only manual chest compressions have been employed in these scenarios and occasionally used as a bridge to left ventricular assist devices or full cardiopulmonary support devices.8–10 Modern mechanical chest compression devices are now available and have been used with some success in the cath lab.11–17 The evidence of success using these devices has led the recently released 2010 guidelines on resuscitation to give the use of mechanical chest compressions in the cath lab a Class IIa rating (C level of evidence).18

Manual Chest Compressions

How to perform manual chest compressions is described in detail in the guidelines and yet they are often insufficiently performed, even outside the cath lab.19–21 Manual chest compressions in the cath lab itself may in fact be harder to perform for several reasons.

First of all, adequate access to the patient and the ergonomics given to the person delivering compressions is frequently suboptimal due to the surrounding equipment in a tightly-packed cath lab. Second, the table in the cath lab – if in the extended position – is not built to withstand the pressure involved during manual chest compressions and may break. This issue can be resolved by:

- placing a support strut underneath the table, which hampers the angiographic images; or
- retracting the table to a more stable position (according to manufacturers’ instructions in cases where manual chest compressions are to be delivered), which does not usually allow any imaging.

Modern cath labs are improving and some are now built to withstand manual chest compressions with the table in the extended position, which does allow simultaneous fluoroscopic imaging. Third, even if the manual chest compressions are performed with the table in the extended position, the quality of the compressions may be diminished by the trampoline effect of the table. This may reduce the quality of the images. Lastly, even if adequate manual chest compressions can be performed with simultaneous fluoroscopy, the arms and hands of the compression provider will reduce the quality of the images. At the same time, the person carrying out the compressions will be exposed to large doses of radiation. Many operators have experienced the ordeal of pulling the table back and forth and felt the horror of...
trying to work on the coronary arteries on a heart that is arrested in a few seconds before returning to manual compressions with the table in the starting position. It is a commonly held opinion among interventional cardiologists that patients in the situations mentioned above infrequently survive. In reviewing the Anglo-Saxon literature, there are only few case reports and series of patients with prolonged cardiac arrest supported with manual chest compressions in the cath lab.\(^3\)\(^{-6}\) The reports demonstrate the feasibility of performing PCI during manual chest compressions with a successful patient outcome, especially during shorter periods of cardiac arrest. The scarcity of reports, however, which are generally on successful cases, may demonstrate a selection bias as well as an illustration of how difficult it is to achieve ROSC in patients with prolonged cardiac arrest in the cath lab using only manual chest compressions.

**Mechanical Chest Compressions**

Mechanical chest compressions have a history dating back to the thumper\(^\text{®}\) device (Michigan Instruments), which is still marketed today. Recently, however, the piston-driven mechanical chest-compression device LUCAS\(^\text{™}\) (Jolife) and the load-distributing band device Autopulse\(^\text{™}\) (Zoll Medical) have both been used in place of manual chest compressions in the cath lab (see Figures 1 and 2). The devices are built to perform chest compressions according to guidelines and have been well demonstrated in animal studies.\(^22\)\(^{-23}\) Importantly they have also been shown to provide adequate coronary perfusion pressure and cerebral circulation in such studies.\(^22\)\(^{-24}\) Measurement of coronary perfusion pressure in humans during cardiac arrest with ongoing mechanical chest compressions in the cath lab has been demonstrated by Larsen et al. in a series of patients there was a correlation between thrombolysis in myocardial infarction-3 flow and coronary perfusion pressure >15mmHg.\(^13\) Of further interest, the trapezoidal-induced pressure waveforms achieved with mechanical chest compression devices due to the rapid onset-offset of compressions may be superior to the more sinusoidal-induced pressure waves achieved with manual compressions.\(^25\)

Both LUCAS and Autopulse have shown the ability to sustain circulation for extended periods of time despite cardiac arrest. There are currently more published reports and presentations on the use of LUCAS for mechanical chest compressions in the cath lab.\(^11\)\(^{-17}\)\(^26\)\(^{-27}\) The anterior–posterior design of the piston means that cranial and caudal angulation views are necessary when performing angiography during the time LUCAS is in place. Fortunately, these views are almost always preferred during percutaneous coronary interventions, even without

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**Figure 1: Illustrations of LUCAS™ (Jolife)**

![Image of LUCAS™](image1)

**Figure 2: Illustration of the Autopulse™ (Zoll Medical)**

![Image of Autopulse™](image2)

**Figure 3: Result of the Pre-percutaneous Coronary Intervention Angiography**

![Image of angiography result](image3)
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LUCAS. Images during mechanical chest compressions in the cath lab are shown in Figures 3 to 6. The Autopulse also provides adequate circulation in cardiac arrest victims. The design of the back plate may, however, require steeper angulated views for fluoroscopic imaging. The Autopulse device has been used successfully during cardiac arrest in the cath lab (personal communication, Gerald Werner, Darmstadt, Germany and Bela Merkely, Budapest, Hungary), although there is limited published data available.27 Its use in the pre-hospital setting is well documented.28

Efficacy

From animal data it is known that LUCAS can maintain a positive coronary perfusion pressure and restore at least 60% of the cerebral flow in pigs.23,24 In humans, a number of successful individual cases and series of patients using mechanical chest-compression devices in the cath lab have now been documented.11,12,15–17 Furthermore, Larsen et al. have documented life-sustaining coronary perfusion pressure using the LUCAS device in the cath lab in a series of patients.13 Figure 7 illustrates a typical arterial blood pressure curve that can be attained in a patient with cardiac arrest undergoing mechanical chest compressions.

Issues to be Addressed

The use mechanical chest compression devices may thus offer several advantages over manual chest compressions in the cath lab, which seem to be substantiated by a number of publications and case presentations at international conferences. There are some issues that, however, need to be addressed. First of all, there have been reports of possible injuries sustained through usage of mechanical chest compressions, although when compared to injuries caused by manual compressions there was no difference.29,30 This issue needs further exploration.

Second, the ventilation of patients with ongoing mechanical chest compressions can be difficult. Patients need to be adequately ventilated without causing trauma to the lungs, which may occur during forceful ventilations within periods of chest compression. This may be remedied by either continuous, frequent ventilations during the decompression phase or by short episodic interruptions of chest compressions for the purpose of larger insufflations. Another method may be through the use of passive insufflation of oxygen through the Boussignac™ tracheal tube (Vygon) during mechanical chest compressions.
**Conclusion**

In summary, none of the devices provide perfect circulation or perfect fluoroscopic images. Sustainable circulation is easily achieved, however, and a continued PCI can still be performed by an experienced operator and often lead to a life-saving procedure despite prolonged cardiac arrest.

**Discussion**

Chest compressions in the cath lab during cardiac arrest have traditionally been performed by manual compressions. The recent introduction of mechanical chest compression devices may offer advantages compared to manual chest compression in cases of prolonged cardiac arrest. This is due to better fluoroscopic imaging during the procedure, better compressions due to an improved aortic pressure waveform and better ergonomics for the cath lab staff. Mechanical chest compressors also allow for a continued, uninterrupted interventional procedure during a potentially life-saving procedure. In light of the numerous reports of successful use of mechanical chest compressions in the cath lab, which have been noted in the recent 2010 Resuscitation guidelines, a case could be made that mechanical chest compression devices should be available to all cath labs. Data are currently severely lacking on the use of manual chest compression in the cath lab in cases with prolonged cardiac arrest. Experience among cardiologists is that it is exceedingly difficult to maintain circulation with manual compressions while continuing the interventional procedure that may be life-saving.2 In these circumstances, mechanical chest compressions may be of benefit. The use of mechanical chest compressions has resulted in more published case reports than were previously available. The devices offer a much better working environment for the cath lab staff and very likely better quality compressions compared to manual efforts, specifically in the cath lab.2–4 It has also been the experience of the authors that with a machine performing the compressions and stabilising the circulation of the patient, a large burden of stress is relieved in an otherwise tension-ridden situation. A common feeling is that this tension relief allows for an improved, continued intervention where the operator can better concentrate on the task at hand. In which patients should a mechanical device be used in the cath lab?

In published case series it appears that patients already in cardiac arrest when brought into the cath lab with ongoing mechanical chest compressions have extremely high mortality rates.14 In contrast, patients who initially arrive alive to the cath lab and then suffer a severe prolonged cardiac arrest may have survival rates of up to 30%.17 Patients in cardiac arrest with re-established circulation only through ongoing mechanical chest compressions should therefore be carefully selected before being brought to the cath lab. The alternative to the use of mechanical chest compression devices as a means to improve survival during prolonged cardiac arrest in the cath lab may be through the use of portable extra corporal membrane oxygenator (ECMO) machines. These are simple to operate and use percutaneously inserted arterial and venous access. ECMO machines may thus hold real promise, not as an alternative to mechanical chest compressions, but rather as a complement. Mechanical chest compression devices have the advantage of being initiated very quickly to stabilise circulation. If required, the patient can then be placed on an ECMO. This may be useful in patients who are difficult to ventilate, such as in cases of pulmonary oedema or in patients still in cardiac arrest following the end of a technically successful intervention.12 Percutaneous cardio pulmonary bypass (PCPB) or percutaneous left ventricular assist devices (PLVADs), such as Impella (Abiomed) or TandemHeart (CardiacAssist), may also be used as an alternative to an ECMO. Several small studies using PCPB and an ECMO in intractable cardiac arrest have reported promising results.8–10,31 ECMO, PCPB and PLVADs seem to be effective but are usually time-consuming to initiate and can require extra staff with special skills, such as a cardiovascular surgeon and a perfusionist.

**Conclusion**

In conclusion, the use of mechanical chest compressions to maintain circulation during prolonged cardiac arrest in the cath lab may be superior to the use of manual chest compressions. The use of mechanical chest compressions can facilitate a potentially lifesaving continued coronary intervention and may also be used as a bridge to ECMO or other means of cardiopulmonary bypass.
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