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PCI in Cardiac Arrest Patients

Percutaneous Coronary Interventions during Automated Chest Compression for Arrest

Thomas Fishman, Vincent Ribordy, Serban Puricel, Mario Togni, Sébastien Doll, Diego Arroyo, Stéphane Cook
Cardiology, Emergency and Intensive Care Units, University and Hospital Fribourg, Switzerland

Summary

Background: The Lund University Cardiopulmonary Assist System-2/-3 was developed for automatic chest compressions during cardiopulmonary resuscitation (mechanical CPR or MCPR) and often allows a patient suffering from cardiac arrest to be taken to the cardiac catheterization room. We report the clinical outcomes of percutaneous coronary interventions (PCI) performed in cardiac arrest patients under automatic MCPR devices.

Methods: We retrieved all patients with cardiac arrest who were referred to PCI under MCPR devices from the Cardio-FR database (003-REP-CER-FR) from January 2016 to December 2021. Patients who were hemodynamically stable at the time of coronary examination/intervention (even those who had been resuscitated immediately before) were excluded from the analysis. Baseline patient and procedure characteristics were collected. The primary outcome was the return of spontaneous circulation (ROSC).

Results: Of all patients who were on MCPR at the cardiac catheterization room, eleven still required active CPR during coronary examination/intervention and were included in the analysis. Mean age was 67.9 ± 10 years, nine were male. The MCPR device was initiated on average after 8.5 ± 8.1 minutes. All patients had ventricular defibrillation and received an average of 3.4 ± 3.6 shocks and 82% adrenaline boluses. The MCPR was used for an average of 51.1 ± 34.4 minutes. Total resuscitation time was on average 59.6 ± 38.3 minutes. Of the eleven patients, nine underwent ad hoc PCI. ROSC was achieved in four patients after 36.5 ± 49.8 minutes. The survival was 36% (four patients) at 24 hours and 27% (three patients) at three months. Only one of the patients resuscitated for >25 minutes survived. Patients with in-hospital cardiac arrest were associated with shorter ROSC ($p < 0.01$), shorter resuscitation time ($p = 0.009$) and better survival ($p = 0.03$) than patients with out-of-hospital cardiac arrest.

Conclusions: MCPR allows patients in cardiac arrest to reach the cardiac catheterization room. However, the prognosis is grim with high mortality. Only one patient survived after >25 minutes of mechanical resuscitation.

Keywords: Sudden cardiac death; cardiopulmonary resuscitation; percutaneous coronary intervention; mechanical chest compression device

Introduction

Sudden cardiac death is the third leading cause of death in Europe and is caused by coronary artery disease in >80% of cases [1]. In acute coronary syndromes, early coronary angiography, coronary revascularization and hemodynamic support resulted in a significant reduction in mortality over the last two decades [2]. In case of cardiac arrest, recent advances in resuscitation with a centralized call, first responders, organization of efficient networks and the possibility of early initiation of advanced techniques allow more patients to be referred to the cardiac catheterization room, sometimes even in the absence of return of spontaneous circulation (ROSC). One of the key steps in the first minutes of cardiopulmonary resuscitation (CPR) is the effectiveness of the external cardiac massage.

Although uninterrupted high-quality chest compressions improve the chance of successful resuscitation and survival without ROSC, it is difficult to perform high-quality chest compressions effectively during percutaneous coronary interventions (PCI) [3–6]. Several automatic chest compression devices have been developed in recent years. Mechanical chest compression devices have advantages in the cardiac catheterization laboratory; they permit uninterrupted chest compressions, no hands in the X-ray beam or head near the image intensifier, fewer people around the catheterization table and better-quality chest com-

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pressions [7]. In animal models, cerebral blood flow during CPR is improved with mechanical CPR (MCPR) and MCPR devices provide significantly higher coronary perfusion pressures than manual CPR [8, 9]. The most widespread MCPR device in Switzerland is the Lund University Cardiac Arrest System version 2 or 3 (LUCAS; Jolife, Lund, Sweden). This MCPR device is a portable chest compression device that incorporates a suction cup for active decompression. In humans, case reports and cohort studies showed that LUCAS devices could produce a sufficient coronary perfusion pressure associated with angiographically verified TIMI 3 flow and have already described favorable outcomes with those devices [3, 10-15]. We started using the LUCAS-2 in the catheter laboratory for patients with ongoing CPR in 2008. Since then, the ambulances, emergency and resuscitation facilities of the Fribourg network have been equipped.

We report the clinical outcomes after PCI in cardiac arrest patients under automatic MCPR devices.

Methods

This was a monocentric retrospective study from the Cardio-FR database. Both out-of-hospital cardiac arrest (OHCA) and in-hospital cardiac arrest (IHCA), who were referred to PCI under MCPR devices in the cardiac catheterization rooms at the University and Hospital Fribourg were included. Since 2008, MCPR devices are routinely used in cases of cardiac arrest by our network partners. This means that in special circumstances, some patients are carried during CPR to the entrance of the cardiac catheterization room. These circumstances happen when a patient has a neurological prognosis that is likely good with a reversible cardiac origin, which includes patients under the age of 80 with witnessed cardiac arrest, a duration of CPR <30 minutes and exclude patients with primary asystole, those with known severe chronic comorbidities and those with a high suspicion of aortic dissection.

Of all the patients in the registry who underwent cardiac catheterization and received MCPR, we focused on those who still required active MCPR at the time of transfer to the examination table. Patients who were hemodynamically stable at the time of coronary examination/intervention (even those who had been resuscitated immediately before) were excluded from the analysis. Baseline patient and procedure characteristics were collected. The primary outcome was the return of spontaneous circulation.

Medical records, including pre-hospitalization medical history, physical examination, laboratory tests, coronary angiography and left ventriculography, 12-lead ECG, PCI reports, as well as post-procedural echocardiography were reviewed. Since end-tidal carbon dioxide and pH data are not systematically collected in medical records, this data is not shown.

The study complied with the Declaration of Helsinki regarding investigations in humans and was approved by the institutional ethics committee at University and Hospital Fribourg, Switzerland (003-REP-CER-FR).

Definitions

ROSC was the restoration of a sustained heart rate with a palpable pulse and/or measurable blood pressure. A sustained ROSC was considered when the circulation persisted for at least twenty consecutive minutes after interruption of CPR [16]. Myocardial infarction was defined according to the fourth definition and categorized into MI with ST-segment elevation (STEMI) and myocardial infarction without ST-segment elevation (NSTEMI) [17]. Death was classified as either cardiac or non-cardiac, according to the Academic Research Consortium definition [18]. Deaths that could not be classified were considered cardiac.

Statistical Analysis

Categorical variables are reported as counts and percentages. Continuous variables are reported as means and standard deviations. Normality was assessed by visual inspection of histograms and a Kolmogorov-Smirnov test. A t-test was used to compare the mean between the groups. The Fisher's exact test was used to compare dichotomous variables. The borderline of significance was $p < 0.05$. Statistical analyses were performed on IBM SPSS Statistics software for Windows version 28.0.1.1.

Results

Population

Between January 2016 and December 2021, 28 patients were on MCPR by admission to the cardiac catheterization room. Of the 28 patients, 17 patients were pronounced dead or had ROSC prior to placement on the examination table. The remaining eleven patients were on MCPR device at the time of coronary angiography: six OHCA patients (55%) and five IHCA patients (45%). These eleven patients compose the study population. Mean age was 67.9 ± 10 years. Baseline patient characteristics are summarized in table 1.

Resuscitation

One patient suffered an initial no-flow of two minutes. Basic life support was initiated immediately in all others. On average, MCPR was initiated after 8.5 ± 8.1 minutes. All patients had initial ventricular fibrillation and were defibrillated with 3.6 ± 3.4 electric shocks. Two patients had transient ROSC after defibrillation. Nine patients received epinephrine boluses. Total resuscitation time was 59.6 ± 38.3 minutes of which 51.1 ± 34.4 minutes with the LUCAS-2/-3. Seven patients (64%) did not achieve sustained ROSC. All of them had a cardiac arrest before entering the catheterization laboratory. Resuscitation characteristics are summarized in table 2.

Coronary Angiography Findings and PCI

Coronary angiogram was performed on all patients. The cause of arrest was considered an acute coronary syndrome (ACS) in nine patients and a non-coronary cause in two. Of the nine patients with coronary artery disease, seven had a left main coronary occlusion

Table 1: Baseline patient characteristics

	All Patients (N = 11)	Non-survivors (N = 7)	Survivors (N = 4)	p-value
Age mean ± SD	67.9 ± 10	68.1 ± 10.1	67.5 ± 11.2	0.46
Male gender, N (%)	9 (82)	5 (71)	4 (100)	0.38
Cardiovascular risk factors				
– Arterial hypertension, N (%)	7 (64)	4 (57)	3 (75)	0.53
– Diabetes mellitus, N (%)	2 (18)	0 (0)	2 (50)	0.11
– Dyslipidemia, N (%)	3 (27)	1 (14)	2 (50)	0.28
– Smoking, N (%)	4 (36)	3 (43)	1 (25)	0.53
Prior CV history				
– STEMI/NSTEMI, N (%)	3 (27)	1 (14)	2 (50)	0.28
– CAD N (%)	5 (45)	3 (43)	2 (50)	0.65
– PCI, N (%)	4 (36)	2 (28)	2 (50)	0.47
– Prior EF<50%, N (%)	2 (18)	1 (14)	1 (25)	0.62

Abbreviations: SD: standard deviation, STEMI: myocardial infarct with ST-segment elevation, NSTEMI: myocardial infarct without ST-segment elevation, CAD: coronary arteries diseases, PCI: percutaneous coronary intervention, EF: ejection fraction

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Table 2: Resuscitation and percutaneous cardiac interventions

	All Patients (N = 11)	Non-survivors (N = 7)	Survivors (N = 4)	p-value
No-flow duration, min ± SD	0.2 ± 0.6	0.3 ± 0.8	0.0 ± 0.0	0.45
N of shocks delivered, ± SD	3.6 ± 3.4	3.7 ± 3.7	1.7 ± 2.1	0.94
Epinephrine, mg ± SD	5.9 ± 2.5	7.3 ± 0.8	2.7 ± 2.1	0.04
Time to MCPR, min ± SD	8.5 ± 8.1	10.7 ± 9.2	6.0 ± 6.4	0.40
Total MCPR duration, min ± SD	51.1 ± 34.4	67.6 ± 27.1	22.3 ± 26.9	0.02
Resuscitation duration, min ± SD	59.6 ± 38.3	78.4 ± 28.6	26.8 ± 31.6	0.01
Time to ROSC, min ± SD	–	–	11.7 ± 11.7	–
Time to TOR, min ± SD	–	79.9 ± 29.4	–	–
PCI, N [%]	9 [81.8]	5 [71.4]	4 [100.0]	0.24
Mean fluoroscopy time, min ± SD	7.3 ± 10.4	3.2 ± 1.4	16.0 ± 19.1	0.26
PVAD/ECMO, N [%]	3 [27.3]	1 [9.1]	2 [50.0]	0.20

SD: standard deviation, MCPR: mechanical cardiopulmonary resuscitation, ROSC: return of spontaneous circulation, TOR: termination of resuscitation, PCI: percutaneous coronary intervention, PVAD: percutaneous ventricular assist, ECMO: extracorporeal membrane oxygenation.

(three due to in-stent thrombosis, four with native disease) and two had an occlusion of the left anterior descending artery. The mean fluoroscopy time was 8.3 ± 11.4 minutes. The amount of contrast media was 104.2 ± 90.5 ml. Nine patients underwent PCI with 1.3 ± 1.5 stents.

Clinical Outcomes

A percutaneous ventricular assist device was implanted in three patients: Impella CP with SmartAssist (Abiomed, Danvers, USA) in one patient and extracorporeal membrane oxygenation (ECMO, CardioHelp, Getinge, Gothenburg, Sweden) in two patients. The survival was 36% (four patients) at one and 24 hours and 27% (three patients) at three months. At three months, all survivors had a normal cerebral performance (CPC category of 1).

Comparison between In-Hospital Survivors and Non-Survivors

There was no significant difference in baseline patient characteristics between both groups. In contrast, patients who survived were more likely to initiate the cardiac arrest within the catheterization laboratory compared to non-survivors (p = 0.02). The resuscitation time (26.8 ± 31.6 min vs. 78.4 ± 28.6 min, p = 0.01) and the duration of MCPR use (22.3 ± 26.9 min vs. 67.6 ± 27.1 min, p = 0.02) were significantly lower in survivors compared with non-survivors.

Discussion

The series we report here demonstrates the feasibility of PCI during ongoing CPR with MCPR device. Furthermore, these cases show that the survival of these patients remains limited despite a controlled mechanical resuscitation. The clinical outcome is particularly poor in patients with OHCA.

Feasibility, Benefits and Risks of MCPR during PCI

The LUCAS-2 and LUCAS-3 devices allow the standard diagnostic coronary angiography views to be taken during ongoing CPR while limiting the exposure of caregivers to X-rays (fig. 1). In pig models, the LUCAS device maintains adequate positive coronary perfu-

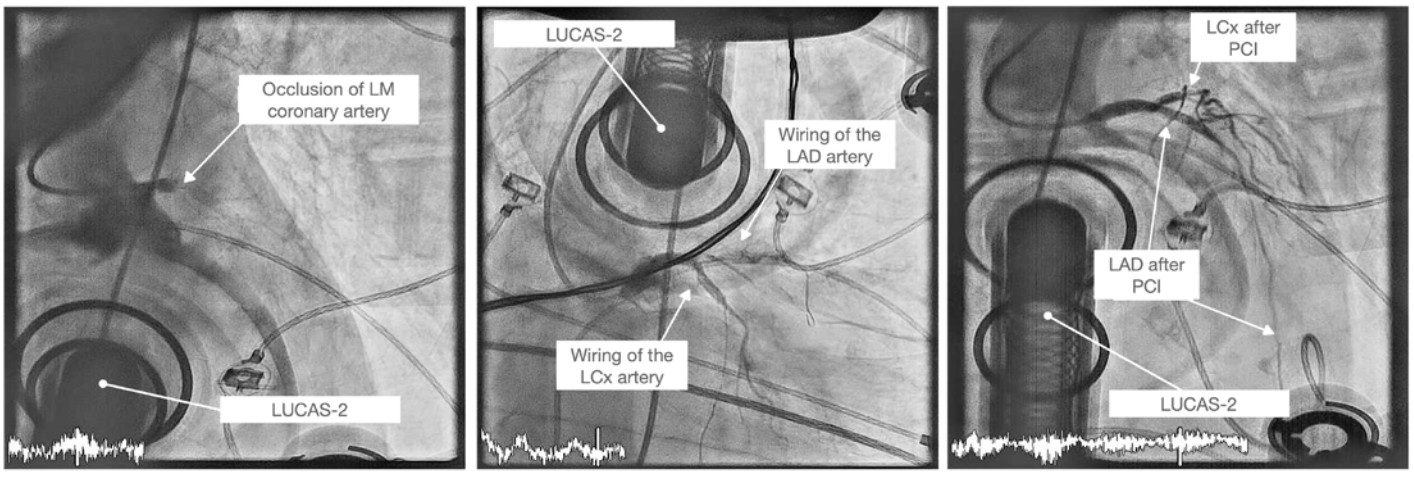

Figure 1: Coronary angiography during percutaneous coronary intervention (PCI) with LUCAS-2 (Lund University Cardiopulmonary Assist System-2). LM, left main artery; LAD, left anterior descending artery; LCx, left circumflex artery.

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sion pressure for 20 minutes and restores 60% of cerebral blood flow for 15 minutes [9, 19]. In humans, Larsen et al. [10] and Wagner et al. [20] have shown, that LUCAS devices could achieve a mean systolic blood pressure of 70 mmHg (range 60–110 mmHg) during PCI. In this series, coronary angiography was performed in all patients, and PCI in nine while receiving adequate CPR. Although we did not record hemodynamic profiles during CPR, we did check for correct setup based on the arterial pressures and occasionally needed to reposition the device for optimal cardiac compressions. In case of incorrect positioning, cardiac massage can lead to mechanical injuries such as pneumothorax, hemomediastinum or liver laceration. As we did not perform autopsies on the seven patients who died, we have no data on iatrogenicity. Lastly, although the system replaces massage by a caregiver under X-ray, the exposure to radiation remains higher than in normal circumstances due to the fact that the image intensifier must be placed at distance from the patient. The system limits the angiography to anteroposterior views and forces the operator to work at distance to avoid touching the device with the fluoroscopy.

Procedural Characteristics

Over the past decade, time has been a significant focus in quality assessment and improvement for care and support of patients undergoing cardiac arrest or myocardial infarction [21–23]. Here, the resuscitation time and the time of MCPR use were significantly higher in non-survivors compared to survivors. Only one patient survived a mechanical resuscitation time of over 25 minutes. Apart from one case reported by Libungan et al. from a 40-minute survivor [33], this observation is consistent with other cases reports and series published so far, summarized in table 3. If virtually no patient survives beyond 25 minutes, it raises the question of when to stop resuscitation.

Predictors of Survival

Several factors have been shown to influence survival after cardiac arrest. Ujvárosy et al. showed an inverse correlation between age, arterial hypertension or left ventricular hypertrophy and outcome [24]. Patients with diabetes mellitus are considered at higher risk during PCI for ACS [25–27]. Here, we found no difference in the patient baseline characteristics. This may be related to the selection of patients (too sick) or the sample size being too small.

What Is the Value of Extracorporeal Cardiopulmonary Resuscitation (ECPR) In These Patients?

ECMO in refractory cardiac arrest is referred to as ECPR (extracorporeal cardiopulmonary resuscitation). Some experts advocate that ECPR should be offered in case of cardiac arrest that is refractory to conventional CPR. The pathophysiological concept is logical. However, practice is limited due to delays of initiation. Only 1% of IHCAs in a large US registry were treated with ECPR [28]. Furthermore, two studies comparing ECPR with standard care did not show an increase in survival with this technique [29, 30]. Bourgouin et al. studied the clinical follow-up of 13,191 patients with OHCA in Paris. ECPR was initiated in 4% of cases but was not associated with improved outcomes compared to conventional CPR. However, some characteristics were associated with better follow-up, such as initial shockable rhythm, short delay and transient ROSC. On the contrary, several observational studies with or without propensity score analysis (such as Chen et al. [35] or Maekawa et al. [36]) have found an improvement in survival during CPR with the assistance of extracorporeal cardiopulmonary support compared to conventional CPR in adults with cardiac arrest. However, the differences in survival observed in Europe and Asia may be due to the definition of refractory cardiac arrest (10–20 minutes in Asia, 30 minutes in Europe). Nevertheless, patient selection is crucial. In this regard, while the PRAGUE study was negative, the latest analysis published by Belohlavek et al. [37] reported a survival rate with CPC 1-2 of 49% in patients with ventricular fibrillation and 5% in those with a non-shockable rhythm. Therefore, patients with initial shockable rhythm and transient ROSC could benefit from an ECRP. Here, two patients out of eleven received ECPR, one was still alive at three months and the other died within eight hours. Finally, this study touches the subject of when to escalate and what is the duration of resuscitation after which any action becomes illusory. Here, under optimal conditions, only one patient survived a resuscitation of over 25 minutes. This is in line with several previous observations which suggest that beyond 20 to 30 minutes, most resuscitations might be futile.

Table 3: Comparisons with previous studies

	Larsen et al. [3]	Larsen et al. [10]	Wagner et al. [20]	Biondi-Zoccai et al. [31]	Azadi et al. [12]	Kalra et al. [32]	Libungan et al. [33]	Wagner et al. [34]	Fishman et al.	All
Publication date	2007	2010	2010	2011	2012	2013	2014	2016	2023	
Inclusion period	2005	NA	2004–2008	NA	NA	NA	2013	2009–2013	2016–2021	
N of patients with active LUCAS-2/-3 device during coronary catheterisation	13	6	39	1	5	12	1	32	11	**119**
OHCA / IHCA	OHCA	OHCA	IHCA	OHCA	IHCA	OHCA / IHCA	IHCA	IHCA	OHCA / IHCA	
Duration of LUCAS-2/-3 use (min)*	105 ± 60	NA	28.2 ± 3.4	NA	NA	63.6 ± 44.2	40	34 (5-90)	51.1 ± 34.3	**42.6**
% in-hospital death	100%	100%	75%	100%	80%	67%	0%	75%	73%	**77%**

Abbreviations: NA: Not available, LUCAS-2/-3: Lund University Cardiopulmonary Assist System-2/-3, OHCA: out-of-hospital cardiac arrest, IHCA: in-hospital cardiac arrest. * mean ± SD or median (range)

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Conclusion

The MCPR device allows patients in cardiac arrest to be maintained on efficient CPR until they reach the cardiac catheterization room. However, the prognosis of these patients remains dismal with high mortality.

Limitation

This study is a single-center case series with limited sample size from which it is difficult to establish firm conclusions.

Correspondence

Prof. Stéphane Cook
Department of Cardiology
University & Hospital Fribourg
CH-1708 Fribourg
stephane.cook[at]unifr.ch

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