

# Preliminary Comparison Study of Two Electro-Mechanical Cardiopulmonary Resuscitation Devices

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## Abstract

*New electro-mechanical cardiopulmonary resuscitation devices may help in providing more constant compressions in depth and compression rate to patients suffering from cardiac arrest. They are easily transportable and allow paramedics to move patients even while applying CPR. The behaviour of these devices however may be different even when using the same guidelines for the effective application of CPR. The presented study shows the hemodynamic and gas exchange response in the application of the Lucas2 and Corpuls CPR device with the use of an animal model. A description of the acquisition system is given and the protocol followed during the experimental procedure.*

## 1. Introduction

Cardiopulmonary resuscitation is an effective way of increasing the chances of survival in people suffering from cardiac arrest. This procedure consists of generating compressions on the chest to re-establish blood circulation. According to international guidelines an effective application of CPR consists on compressions of at least 5 cm deep at a rate of at least 100 per minute [1]. Maintaining these guidelines however may become difficult even for trained paramedics due to the amount of force and continuity required. Additionally patients may not be easily transported when compressions are being applied.

Over the past years new types of electro-mechanical resuscitation devices (ERD) have been developed in an effort to overcome these difficulties, each of them with different mechanical characteristics [2]. This paper describes the comparison of two of these electro-mechanical CPR devices from a hemodynamic perspective with the use of a porcine model.

A detailed description is given of the experimental setup, the measurement devices and the protocol that was carried out in the various experiments. The presented

results show the differences in flow, mean arterial pressure, oxygen saturation and gas through the experimental procedure.

## 2. Methods

Domestic pigs were used in these experiments, with a weight of 25-30 kg. Experiments were approved by Bavarian authorities (AZ 2532-205-13) and the animals received humane care in compliance with Guide of the Care and Use of Laboratory Animals (NIH publications 85-23). The study was divided in two groups, with four pigs on each group. The first was to evaluate the Lucas 2 device, and the second for the evaluation of the Corpuls CPR device.

For the monitoring of vital parameters during the experiments a Data Acquisition System (DAS) was created using the AutoMedic Platform developed in our research group[3]. The system consists of various sensors, acquisition device or transducer which obtains the vital parameters from the sensors and communicates this information to the acquisition system through a dedicated communication interface. The system gathers this data, which is stored for post-operative analysis and is displayed to be used during the procedure.

For the acquisition of ECG four electrodes were placed

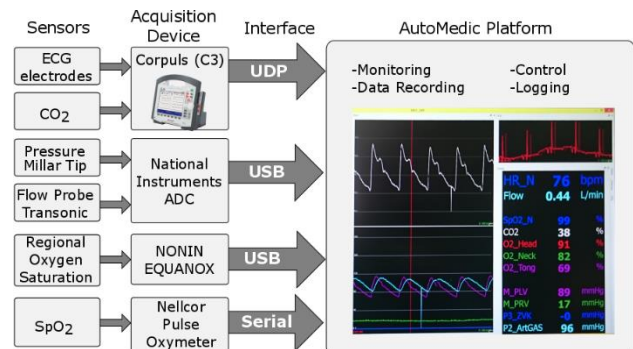


Figure 1 Acquisition System for vital parameters using AutoMedic Platform

in the pig and connected to a Corpuls C3 monitor (GS

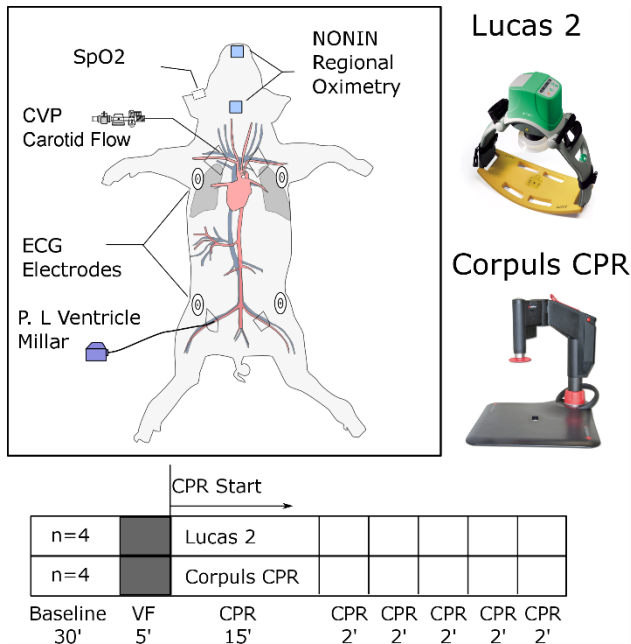


Figure 3 Experimental setup and protocol, with electro-mechanical CPR devices.

GmbH, Kaufering, Germany). Additionally an infrared sensor was placed in the ventilation tubing for the acquisition of capnography curve and CO<sub>2</sub> values, which was also connected to the Corpuls C3. This device sent data to the DAS through a UDP connection, sending an ECG signal at 500 Hz and a CO<sub>2</sub> value at 1 Hz.

For the acquisition of pressure catheter tip manometers (Millar MIKRO-TIP SPC350, Houston, TX, USA) were used connected to a NI DAQ board. (NI BNC-2110, National Instruments, Austin TX) for analog to digital conversion. Flow was obtained using an ultrasonic flow probe from Transonic (C-Serie, Transonic Systems Inc, Ithaca, NY, USA) which was also connected to the NI DAQ. The NI DAQ was configured to sample at 200 Hz with a resolution of 16 bits. This was connected to the DAS through USB and the NIDAQmx library was used for communication.

The animals were pre-medicated by intramuscular injection with a mixture of ketamine (15mg / kg; 10% ketamine, Bela Pharm, Vechta, Germany), Azaperon (2mg/kg; Stressnil®, Lilly, Bad Homburg, Germany) and Atropin (0,02mg/kg; B.Braun, Melsungen, Germany). After sedation, a 18 G plastic cannula (Vasofix, B. Braun, Melsungen, Germany) was placed on the ear for application of medication. The anesthetic induction was carried out by intravenous bolus injection of propofol, midazolam (10mg / kg, propofol 2%, 1mg/kg midazolam,

B.Braun, Melsungen) and fentanyl (fentanyl, Janssen-Cilag, Neuss, Germany). This was followed by intubation by tracheotomy (7.0 frilly, Teleflex, Malaysia) and mechanical ventilation (Vt: 10 ml / kg, AF: 10-18; FiO<sub>2</sub>: 0,21-0.3; Pmax: 45 mbar, PEEP: 0-5 mbar; Dräger Evita II). Anesthesia and analgesia was administered by continuous propofol 8mg / kg / h via a syringe pump and fentanyl 25 .mu.g / kg / h.

After proper anesthesia all the sensors were placed; the Millar tip® was introduced through the right femoral artery and the flow probe was placed on a carotid artery.

Figure 2 shows the placement of the sensors and on the bottom the followed protocol is depicted. A baseline recording was done before starting the CPR procedure. Afterwards the heart was put into fibrillation and was left to rest for 5 minutes, stopping also the ventilation. Once the 5 minutes finished the CPR was started using one of the electro-mechanical devices corresponding to the specific experiment. Both devices were set to perform CPR with a depth of 5 cm at 100 compressions per minute. After 15 minutes of continuous CPR the device was stopped and the ECG signal was checked for electrical activity, ventricular fibrillation (VF), ventricular tachycardia (VT) or asystole. If a VF or VT signal was found a shock was induced by a Corpuls defibrillator. After this event CPR was continued for two more minutes, checking again for electrical activity and restarting CPR. The two minute interval of CPR and rhythm assessment was repeated for five times or after return of spontaneous circulation.

After a total time of 25 min of CPR the experimental procedure was terminated.

### 3. Results

Figure 3 shows the case of carotid flow in two experiments, one for each device where the left graphs show 3 seconds in the baseline period, before inducing VF and applying CPR and the right graphs show the carotid

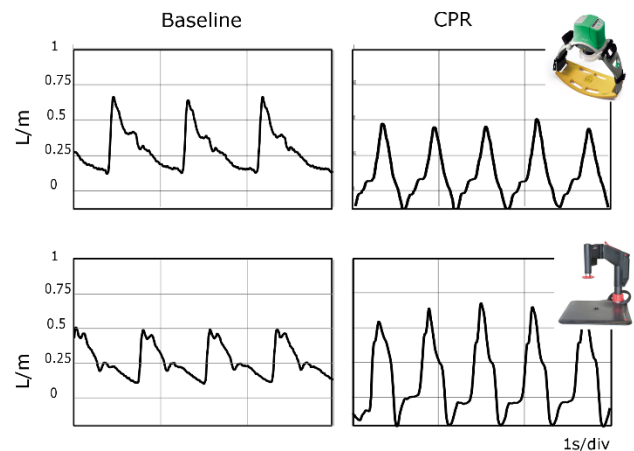


Figure 2 Comparison of carotid flow at baseline and during CPR

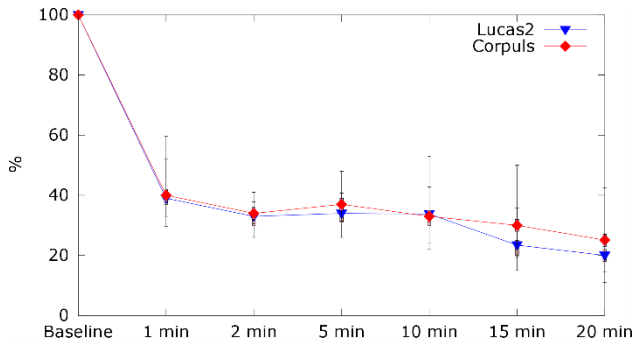


Figure 4 Change of carotid flow rate during CPR compared to Baseline shown in percentage.

flow during CPR with the electromechanical device generating the chest compressions.

To evaluate the change of carotid blood flow before and during CPR the baseline flow was taken as 100% for each individual experiment and the corresponding percentage was calculated throughout the different phases at 1min, 2 min, 5 min, 10, 15 and 20 minutes. These values were then averaged through all the experiments corresponding to each device, the results are shown in figure 4.

What we can observe is that on the first minute of CPR in average 40% of the baseline flow could be generated, after one minute this was decreased to approx. 35%, after 5 minutes there is a slight gain in carotid flow to 36% on the Lucas2 device and 37% on the Corpuls device. After 10 minutes the flow rate is back to 33% and 32% correspondingly and after 15 minutes the flow rate starts to gradually decrease, reaching 21% for the Lucas device and 25% for the Corpuls device.

With respect to the mean arterial pressure (MAP), most of the experiments started at baseline at  $85 \pm 10$  mmHg.

After the first minute of CPR the MAP reached 31mmHg for the Lucas device, and 38mmHg on the Corpuls device. The subsequent MAP values may be observed in table 1 and figure 5. These results show a difference of pressure of  $15 \pm 5$  mmHg higher for the Corpuls device compared to the Lucas2 device.

	Baseline	1	2	5	10	15	20	min
Lucas2	87	31	34	26	30	24	18	mmHg
Corpuls	85	38	44	42	45	34	32	mmHg

Table 1 Mean arterial pressure values at Baseline and during CPR

The results of the regional oxygen saturation and carbon dioxide concentration are shown in figure 4 and table 2. Both devices started with a rO2 of  $74.5 \pm 5$  % which decreased to 65 % with a change of  $\pm 10$ % throughout the experiment. The difference between both devices was not significant.

From the CO2 analysis both devices started at  $37 \pm 2$

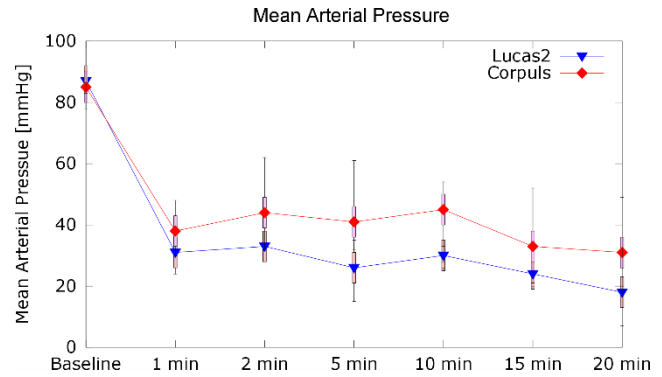


Figure 5 Comparison of MAP between electro-mechanical devices during CPR

mmHg and decreased to  $25 \pm 3$  mmHg for the Lucas2 device and  $20 \pm 3$  mmHg for the Corpuls device. During the CPR procedure the CO2 of the Corpuls device was slightly lower, with a significant increase after 5 minutes. After this period both devices had an equivalent CO2 value.

	Baseline	1	2	5	10	15	20	min
Lucas2 rO2	75	66	67	68	68	67	67	%
Corpuls rO2	74	64	69	72	66	64	62	%
Lucas2 CO2	37	25	27	26	23	20	15	mmHg
Corpuls CO2	37	20	22	35	20	18	15	mmHg

Table 1 CO2 and regional oxygen saturation values for Lucas2 and Corpuls device during CPR

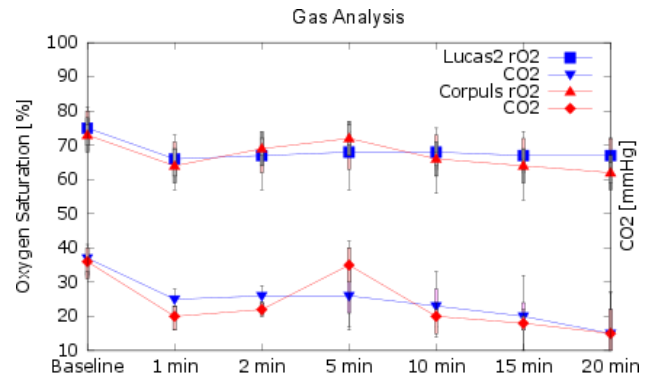


Figure 6 Comparison of CO2 and rO2 between during CPR

## 4. Discussion

The use of a porcine model may be different to the behavior on humans since the anatomy and proportions of the pig are different, also at the thoracic cavity. Even with these differences however with the presented study it was possible to obtain hemodynamic and physiological response to the application of CPR with different electro-mechanical devices and study their efficiency.

In terms of flow generation both devices were capable of generating equivalent flow with a slightly higher perfusion at longer periods of CPR application for the Corpuls CPR device as shown in figure 4. It can be observed that once CPR is started the blood flow measured

at the carotid showed a negative value as shown in figure 3. This effect is consistent with other studies showing similar behavior [3-5].

The pressures produced by the Corpuls device were higher than the Lucas2. This indicates that even when using the same configuration of depth and compression frequency the devices may have a different effect on body perfusion depending on the shape of the compression curve. A previous study analyzed this matter through the use of a mathematical model, showing that a more trapezoidal shape with a longer hold time at full compression depth could produce more flow [6]. The Corpuls CPR produces a more trapezoidal shape, while the Lucas2 device has a more sinuous compression. This in turn may generate a higher pressure, suggesting also an increase of perfusion to the organs. The counter effect of this matter however may be the damage caused on the chest, increasing the risk of rib rupture due to the amount of force needed to generate such compressions.

The electro-mechanical CPR devices that were used for the presented study did not perform any type of adaptation to the compression curve or force applied to the chest. The compression depth and rate was kept constant through the complete procedure. Information about the generated flow and pressure could give some suggestions of how to change these parameters to reduce the risk of organ damage, however the acquisition of these vital parameters can only be done in an invasive manner. Using regional oximetry could be another way of measuring the effectiveness of the CPR, however the experimental results showed that the measurements were not consistent, and the sensor was not as responsive to sudden events throughout the procedure. Capnometry could also give a hint of the effectiveness of CPR, however further study would need to analyze if this parameter can be used to adjust CPR compression parameters.

The advantages of using ERD in the application of CPR is clear from the operative point of view, since it reduces the strenuous work load on the person applying CPR and allows an easier transportation of the patient from the field to the hospital. There is still no consistent evidence that using such devices may improve patient outcome compared to manual chest compressions [7-8]. Further research is required to improve the performance of such devices through the adaptation of the compression shape, depth and frequency depending on the individual characteristics of the patient and response throughout the resuscitation procedure.

## 5. Acknowledgements

This work has been supported by an unrestricted educational grant from the Bayerische Forschungsförderung

## 6. References

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