PHYSIO CONTROL

LUCAS® CHEST COMPRESSION SYSTEM

Selected Bibliography Summaries

April 2012

Prehospital Studies with Control Group

Maule Y. The aid of mechanical CPR; better compressions, but more importantly – more compressions… (translated from French language; Assistance Cardiaque Externe; Masser mieux, mais surtout masser plus…). *Urgence Pratique*. 2011;106:47-48.
This is a French retrospective study that compared compression ratios (the amount of time compressions were being delivered compared to the total CPR time) of the LUCAS chest compression system to that of manual compression. CODE-STAT™ 7.0 Data Review software was used to analyze the data. Two cohorts, consisting of 200 recordings each of non-traumatic CPR, were randomly created. Total duration of CPR was 41 minutes, 20 seconds (+/- 5 min., 15 sec.). The average compression ratio for cases using the LUCAS device was 93% (+/- 4%). The compression ratio for cases using manual compressions was 69% (+/-6%). The author concludes that based on these ratios, mechanical chest compression devices, regardless of the type, allows for optimization of compression times during CPR.

Carmona Jiménez F, Padró P, García A, Martín R, Venegas J, Naval E. Cerebral flow improvement during CPR with LUCAS, measured by Doppler. *Resuscitation*. 2011; 82S1: 30. AP090. (This study is also published in a longer version, in Spanish language with English abstract, in *Emergencias* 2012;24:47-49.)
This is a Spanish prospective study which compared the middle cerebral artery flow (measured by Doppler at 5-6 cm) during manual chest compressions and then during LUCAS™2 chest compressions in six pre-hospital cardiac arrest patients. In three patients no data could be recorded due to early ROSC or no flow due to subarachnoid hemorrhage. In three patients the median flow during manual chest compressions was 31.6+8.32 cm/s which increased to 50.6+17.12 cm/s during LUCAS compressions. The authors mention that normal flow for a healthy person is 60-80 cm/s. The authors concluded that LUCAS seems to improve cerebral flow compared to manual CPR.

Smekal D, Johansson J, Huzevka T, Rubertsson S. A pilot study of mechanical chest compressions with the LUCAS™ device in cardiopulmonary resuscitation. *Resuscitation*. 2011;82:702–706.
This is a Swedish, two-centre, randomized pilot study on LUCAS™1(V1) CPR vs. manual CPR in out-of-hospital patients (N: 75 vs. 73). It showed no significant difference in ROSC rates (30/75 (40%) pts. vs. 23/73 (32%) pts. p=0.30), no significant difference in number of patients hospitalized alive (18/75 (24%) pts. vs. 15/73 (21%) pts. p=0.69) and no significant difference in patients discharged alive from hospital (6/75 (8%) pts. vs. 7/73 (10%) pts. n.s.) with LUCAS vs. manual CPR. The data has been used for the power calculation of the LINC trial (LUCAS IN Cardiac arrest randomized multicentre trial).

This study was published in abstract format in 2007: Rubertsson S, Huzevka T, Smekal D, Johansson J. Early survival after cardiac arrest in a pilot study using the LUCAS device compared to manual chest compressions during CPR. *Circulation*. 2007;116: II 386 Abstract 1813.

Saussy J, Elder J, Flores C, Miller A. Optimization of cardiopulmonary resuscitation with an impedance threshold device, automated compression cardiopulmonary resuscitation and post-resuscitation in-the-field hypothermia improved short-term outcomes following cardiac arrest. *Circulation*. 2010;122:A256. (Poster on file at Physio-Control.)
This a retrospective pre-hospital study from New Orleans EMS system comparing the results after implementing LUCAS™1(V2) , the Impedance Threshold Device and post-ROSC in-field hypothermia (N: 180) in December 2009 to end of September 2010, with historical data (N: 374). Stable ROSC increased to 36% (38/106) compared to 21% (78/374) ($p<0.002$). 69% (58/84) of the patients in which $EtCO_2$ was measured had an increased $EtCO_2$ value, and in 36% (30/84) this increase was over 10mm. $EtCO_2$ is a surrogate for circulation. There were no major adverse events. The authors concluded that the implementation of the devices was feasible, safe and resulted in a 71% increase of stable ROSC.

Axelsson C, Karlsson T, Axelsson Å, Herlitz J. Mechanical active compression-decompression cardiopulmonary resuscitation (ACD-CPR) versus manual CPR according to pressure of end tidal carbon dioxide (PETCO2) during CPR in out-of-hospital cardiac arrest (OHCA). *Resuscitation*. 2009;80(10):1099-1103.
This prospective, cluster randomized Swedish study of 126 pre-hospital cardiac arrest patients showed that LUCAS™1(V1) (N:64) created significantly higher PETCO2 values compared to manual CPR (N:62) with an average value of 3.26 vs. 2.69 kPa, $p = 0.04$. There were no differences in survival, probably due to the fact that the study inclusion was late, about 20 minutes after the cardiac arrest occurred, and the patients constituted a high risk group with a very low overall survival. PETCO2 is a practical, non-invasive method that correlates well with circulation, such as pulmonary blood flow and cardiac output, and is known to be an almost immediate indicator for return of spontaneous circulation. PETCO2 has also been used as an indicator for rescuer fatigue.

Box M, Watson J, Addison P, Clegg G, Robertson C. Shock outcome prediction before and after CPR: A comparative study of manual and automated active compression—decompression CPR. *Resuscitation*. 2008;78:265-274.
This is a British, non-randomized, observational clinical study that compares efficacy of manual chest compressions with LUCAS™ 1(V1) by quantifying metric changes in the ECG signals. These changes indicate an improved state of the myocardium and are predictive of shock success (if the patient is in VF). The metric measurement “cardioversion outcome prediction” (COP) was computed from the pre- and post-CPR ECG trace segments. A total of 212 tracings from out-of-hospital cardiac arrest patients were analysed of which 114 manual CPR tracings and 98 LUCAS CPR tracings.

The results for patients in VF (87 tracings) indicate that CPR did provide beneficial preparation of the heart prior to defibrillation therapy in both manual and automated CPR groups. The increase in COP due to manual CPR was not significant ($p > 0.05$) whereas the automated CPR was found to be significant ($p < 0.05$). This increase was larger for LUCAS CPR (1.26, $p = 0.024$) than for the manual CPR (0.99, $p = 0.124$). The results for all patients and rhythms (212 tracings) showed that both types of CPR increased the COP values, however, LUCAS CPR a more pronounced increase. Subanalyses adjusted for pre-CPR value and length of CPR showed no significant difference between LUCAS or manual CPR. However, the authors recommended that a substantially larger dataset is used to confirm these significance findings.

Olsson P, Steen S, Kongstad P, Sjoberg T. The outcome of cardiac arrest the years before and after introduction of LUCAS in the ambulances. *Resuscitation*. 2008;77S:S9: AS-023.
This study evaluates the outcome of pre-hospital cardiac arrest in Lund, Sweden, before (Period I; year 2000-2002, three years, N: 85) and after (Period II; year 2003-2006, four years: N:187) implementation of LUCAS™1(V1). The overall incidence of out-of-hospital cardiac arrests was similar during the two periods. The introduction of LUCAS was associated with a 68% increase in the number of pre-hospital resuscitation attempts (from 28.3 to 46.8 cases per year), with a 63% increase in the number of patients surviving to hospital admission (from 14 to 22.5 patients per year), and with a 77% increase in the number of patients surviving more than 30 days (from 3.0 to 5.3 patients per year). Interestingly, if the cardiac arrest took place more than 10 km from the hospital no patient survived >30 days during Period I whereas 9 patients survived >30 days during Period II.

Olson H, Rundgren M, Silverstolpe J, Friberg H. Out-of-hospital cardiac arrest—A panorama in transformation. *Resuscitation*. 2008;77S:S47. Abstract. (Poster on file at Physio-Control.)
This is an in-hospital analysis of how the implementation therapeutic hypothermia after cardiac arrest as well as pre-hospital implementation of the LUCAS™1(V1) device together with a new compression-algorithm – all introduced during 2003 in Lund, Sweden - affected the flow of patients to the hospital, survival and 6-months outcome.

During period 1 (1999-2002) a mean of 30 patients/year were admitted to the ER and a mean of 15 patients were admitted to the ward. During Period 2 (2003-2006) an increasing number of patients were admitted to the ER (40, 60, 70, 80/year). The number of patients admitted to the ward increased to 20 (2003) and 30/year (2004-2006). At 6 months, 11% of patients from Period 1 were alive and 7% of them had good neurological outcome. These numbers improved in Period 2. Improved prehospital care (including LUCAS implementation) and hospital care resulted in improved 6-month outcome.

Olasveengen T, Wik L, Steen P. Quality of cardiopulmonary resuscitation before and during transport in out-of-hospital cardiac arrest. *Resuscitation*. 2008;76:185-90.
This is a Norwegian retrospective, observational study of CPR hands-off ratio on scene compared to during transport while treating pre-hospital cardiac arrest patients who received manual CPR (N: 36) or who got LUCAS™1(V1) CPR (N:7). With manual CPR the hands-off ratio increased from 0.19±0.09 on-scene to 0.27±0.15 (p = 0.002) during transport. Quality was significantly better with mechanical than manual CPR with no difference in hands-off ratio on scene (0.10 ± 0.06) vs. during transport (0.08 ± 0.06)(p = 0.248). The hands-off ratio over the entire episode of approx. 33 - 40 minutes was 0.22 ± 0.09 with manual CPR and 0.09 ± 0.06 with LUCAS CPR.

Maule Y. Mechanical external chest compression: a new adjuvant technology in cardiopulmonary resuscitation. (Translated from French language :L'assistance cardiaque externe: nouvelle approche dans la RCP.) *Urgences & Accueil*. 2007;29:4-7.
This publication describes the implementation and early results of LUCAS™1(V1) CPR at the Brugmann University Hospital in Belgium. 150 consecutive out-of-hospital cardiac arrest patients receiving LUCAS CPR (N: 123) or manual CPR (N: 27) were analyzed and compared to historical data on manual CPR (N: 140). The ROSC data with LUCAS (57.7%) was more than double as high compared to both the contemporary manual group (25.9%) as well as the historical manual group (22.2%). LUCAS CPR improved the physiological values of the patients; e.g. systolic blood pressure could be measured during LUCAS CPR which is hardly ever possible during manual CPR, SaO2 readings were around 95%, patients showed signs of life again (moving, etc.) while they were still in VF or had a heart rhythm that produced no blood flow. In addition, LUCAS created an option to transport patients with effective CPR and freed up resources to focus other life-saving tasks.

Axelsson C, Nestin J, Svensson L, Axelsson Å, Herlitz J. Clinical consequences of the introduction of mechanical chest compression in the EMS system for treatment of out-of-hospital cardiac arrest – a pilot study. *Resuscitation*. 2006;71:47-55.
This was the first cluster-controlled pilot study (N: 328) on LUCAS™1(V1) CPR vs. manual CPR in the out-of-hospital setting in Sweden. LUCAS was placed in the second tier and applied very late in the resuscitation process (18 minutes after collapse). The results on ROSC (both groups: 51%), hospitalized alive (38% in LUCAS and 37% in manual group n.s.) and discharged alive (8% vs. 10% n.s.) were the same in both groups. The majority of the survivors had CPC score 1 or 2 in both groups with no significant difference between the groups. During training, LUCAS was applied with CPR hands-off time of less than 20 seconds. The device proved to be impact resistant and dependable. Resuscitation efforts were facilitated by freeing the hands of the rescuer from chest compression. For the same reasons, safety increased during transport in a moving ambulance. LUCAS fit on >98% of the patients.

Pre-Hospital Patient Series and Case Reports

Yost D, Phillips R, Gonzales L, et al. Assessment of CPR interruptions from transthoracic impedance during use of the LUCAS™ mechanical chest compression system. *Resuscitation*. 2012 Feb 4. [*Epub ahead of print*]
This is a retrospective US pre-hospital analysis of CPR interruption time when applying and using LUCAS™1(V2) by looking at transthoracic impedance data transcripts from 32 pre-hospital cardiac arrest patients. The analysis showed it was possible to apply LUCAS with interruptions of less than 20 seconds in ~16% of the cases, whereas 25% had an interruption time of over 1 minute. The median interruption time was 32.5 seconds (Interquartile Range IQR 25-61 sec). The perceived interruption time by the rescuer correlated poorly to the real (pauses were often double as long as perceived).The compression fraction during mechanical CPR was 0.88. The authors conclude that training on application technique is key to keep the interruption time at a minimum and that impedance data can provide objective feedback on use of mechanical CPR devices.

Dembeck A, Sonntag J, Liechti B, Becker M. Reanimation in alpinem Gelände – der etwas andere Einsatz (Resuscitation in the alpine terrain – a slightly different ambulance mission - Article in German language and abstract in English). *Notfall Rettungsmed*. 2012;15:51-57.
This is a Swiss alpine case report on a 70 yr. old man who had acute chest pain and dyspnea while walking in the alps at a 2000 m altitude. The thick mist made it impossible for the rescue helicopter to fly, and a rescue team had to walk and search for the patient, in snowy ground, and wet, cold weather. After more than 2 hours, the rescue team found the man alive but cold and exhausted. After 40 minutes of transporting the patient in the steep alpine terrain, partly using ropeway, the man went into cardiac arrest. A defibrillator and LUCAS™ 2 was brought and applied to the patient. After 30 minutes of resuscitation with LUCAS 2 and seven defibrillations, the patient achieved ROSC. The transportation of the patient down the alps continued two more hours until the rescue ambulance was reached and the patient could be taken to the hospital. The now hypothermic patient had a successful PCI of the occluded coronary arteries that had caused the arrest. The patient was discharged without any neurological deficits after 11 days and is now hiking in the alps again. This case report contains many interesting photos of the challenging resuscitation and is the first publication on LUCAS use in the alpine environment.

Chenaitia H, Fournier M, Brun J, Michelet P, Auffray J. Association of mechanical chest compression and prehospital thrombolysis. *Am J Emerg Med*. 2011 Jun 22. [Epub ahead of print].
This is a pre-hospital case report on a 54 yr. old woman who had chest pain and dyspnea and went into PEA during pre-hospital physical examination by the mobile ICU team. Massive pulmonary embolism was suspected and pre-hospital thrombolysis was initiated during mechanical chest compressions with the LUCAS™ 2*. After 75 minutes of effective chest compressions the patient achieved ROSC. The patient regained consciousness the next day at the ICU, and three weeks later she was sent home in good neurological condition (CPC score 1). The authors discuss that prolonged CPR may lead to mechanical fragmentation of the pulmonary emboli, which enhances the effect of the thrombolysis.

* LUCAS 2 is not mentioned in publication, but was confirmed by Dr. Chenaitia.

Van Gerven E, Keirens A, Muysoms W, Steinkamm C, Verbelen J, Gillis M. Combination of a mechanical active compression-decompression cardiopulmonary resuscitation mechanism (LUCAS 1 and the Boussignac tube) during CPR in out-of-hospital cardiac arrest. *Resuscitation*. 2011;81(S1):S31 AP094.
This is a pre-hospital observational patient series (N: 58) investigating the combination of LUCAS™ 1(V1) and the Boussignac tube as ventilation method. ROSC was achieved in 24 (41.4%) patients and 9 survived (15.5%). The authors conclude that the combination increased success rates compared to general statistics for Europe and US (survival rates of 10.7% and 8.4% respectively) and that the fully hands-free CPR was accepted by great enthusiasm by the users.

Satterlee P, Boland L, Johnson P, Hagstrom S, Lick C. Implementation of mechanical chest compression device as standard equipment in a large, urban ambulance system. *Resuscitation*. 2010;81S:S62. AP111. (Poster on file at Physio-Control.)
This is a pre-hospital patient series (N: 465) describing the broad implementation, and evaluating the feasibility, of LUCAS™ 1(V2) in St Paul (MN, USA) between May 2008 to June 2010. The device fit 96.3% of the patients. The ease of use and perceived effectiveness were rated very high by the users, they found it lightweight and smart packaged and they also commented on the device helping to create a calmer scene and allowing them to take a step back and be more focused as they directed the care. The device was applied from bag to the patient in less than 1 minute in 81% of the cases, The interruption of manual CPR during LUCAS application was less than 20 seconds in 72% of the cases. No adjustments needed to maintain proper position in 74% of the cases. The ROSC rates were 32%. The authors concluded that device was easy to learn and simple to use.

Kyrval H, Ahmad K. Automatic mechanical chest compression during helicopter transportation. (Article in Danish, Abstract in English.) *Ugeskr Laeger*. 2010;172:3190-3191.
This is a Danish case of a drowned, hypothermic trauma patient. After falling from a 25 meter high bridge into 2°C water, she was rescued lifeless 17 minutes later. Advanced life support was initiated. During transport by a rescue helicopter, chest compressions were effectively provided by LUCAS™ 1(V1). Upon arrival to a trauma centre approx. 60 minutes later, extracorporal circulation was set up during LUCAS CPR and the patient was rewarmed during 9.5 hours. She was eventually discharged to her home with minor loss of cerebral function. The authors commented that LUCAS provided effective compressions during helicopter transport, something that is difficult to achieve manually.

Yost D, Gonzales L, Lick C, et al. Abstract 38: North American LUCAS Evaluation: prehospital use of a mechanical chest compression system. *Circulation*. 2010;122:A38. (Poster on file at Physio-Control.)
This is a prehospital patient series (N: 332) evaluating the feasibility of 66 LUCAS™ 1(V2) devices when used in four large US EMS systems; Austin (TX), St Paul (MN), Anchorage (AK) and Contra Costa (CA). The device fit 95% of the patients (317/332). It was estimated that the pause in CPR for LUCAS application was less than 20 seconds in 71% of the cases. On a scale of 1 to 10, providers rated the ease of use of LUCAS to an average of 9.0+ 1.4 and a perceived effectiveness of LUCAS to provide quality compressions on a scale of 0 to 10 to an average of 9.3 +1.4.

Prause G, Archan S, Gemes G, et al. Tight control of effectiveness of cardiac massage with invasive blood pressure monitoring during cardiopulmonary resuscitation. *Am J Emerg Med*. 2010;28:746.e5-1746.e6.
This is a case report from Graz, Austria, where a 69 year old pre-hospital refractory VF patient successfully was saved with manual CPR on the scene and during helicopter transportation, and then LUCAS™ 1(V1) during a life-saving PCI procedure. The effectiveness of manual CPR was monitored with invasive blood pressure measurement by an arterial line and motivated the rescuers to continue. At 60 minutes, the patient was still in VF and showing signs of life and the decision was taken to fly him to the hospital to do a PCI. During 28 minutes of coronary intervention with help of LUCAS CPR, the right artery was successfully treated and ROSC achieved; in total 1 hour and 57 minutes after the cardiovascular collapse. The patient was discharged 2 weeks later without any neurological deficit. The authors conclude that this case illustrates the chance of survival for a patient with out-of-hospital cardiac arrest and prolonged CPR and that the “no transport during CPR” paradigm may need to be revised.

Gonzales L, Langlois J, Parker C, Yost D. Combined interventions may improve success when treating sudden cardiac arrest. *Prehosp Emerg Care*. 2010;14:222-228.

This is a case report from Austin, US, describing the use of LUCAS™ 1(V2) in a pre-hospital, 60-year-old patient with a sudden cardiac arrest due to acute myocardial infarction. The patient refibrillated several times at the scene and got LUCAS CPR on and off during 36 minutes of resuscitation. The authors noted that the device was applied quickly with interruptions of manual CPR of approximately 10-20 seconds and with a total application time of less than 30 seconds. After ROSC was achieved, the patient was transported (LUCAS still applied but not operating) to the hospital for emergent coronary revascularization and continued cooling. On day 14 the patient was discharged to his home with good cerebral performance (CPC1). The authors further discussed the importance of a system-of-care approach to sudden cardiac arrest, including simultaneous implementation of several recommended resuscitation interventions; improved bystander CPR with dispatch compression-only CPR, mechanical CPR, pre-hospital cooling and post-resuscitation care with PCI and cooling.

Matevossian E, Doll D, Säckl J, et al. Prolonged closed cardiac massage using LUCAS device in out-of-hospital cardiac arrest with prolonged transport time. *Open Access Emerg Med*. 2009;1:1-4. www.Dovepress.com
This German case report describes a 44-year-old patient who – approximately 15 min after the onset of clinical death due to VF– received CPR; initially manual followed by LUCAS™ 1(V1) compressions. After 90 min of CPR and seven defibrillations ROSC was achieved. After a 16-day period of hospital convalescence followed by rehabilitation, the patient was able to return home with no evidence of health impairment. The authors conclude that LUCAS contributed to a favorable outcome in the context of prolonged out-of-hospital cardiopulmonary resuscitation.

Gillis M, Keirens A, Steinkamm C, Verbelen J, Muysoms W, Reynders N. The use of LUCAS and the Boussignac tube in the pre-hospital setting. ERC congress 2008. (Poster 219 on file at Physio-Control.)
This Belgian study evaluates the combination of LUCAS™ 1(V1) CPR with the ventilation method using the Boussignac tube on 48 pre-hospital cardiac arrest patients. 38 patients got the Boussignac tube, 10 did not. Due to the small sample size there was no significant differences between the groups. 21% of all the patients had VF, 60% had asystole and 13% PEA. Of the 48 patients, 18 pts.(37.5%) got ROSC and 7 were alive to be admitted to the ICU in a good neurological state (CPC 1 or 2).

Nielsen N, Sandhall L, Scherstén F, Friberg H, Olsson S. Successful resuscitation with mechanical CPR, therapeutic hypothermia and coronary intervention during manual CPR after out-of-hospital cardiac arrest. *Resuscitation*. 2005;65:111-113.
This is a Swedish case-report on a 62-year-old man who suffered out-of-hospital cardiac arrest and was treated with LUCAS™ 1(V1) during transport to the hospital. In the emergency department, ROSC was achieved, and the patient was transferred, deeply comatose, to the cath lab while therapeutic hypothermia was induced. In the cath lab the heart arrested again and CPR was resumed. Coronary angiography was performed during manual CPR revealing a left main stem occlusion. Manual CPR was conducted over periods of approximately 30 s alternating with 20 s of fluoroscopy during the PCI. (LUCAS was not used as they did not think it would fit in the X-ray equipment). After successful reperfusion of the heart and the insertion of an intra-aortic balloon pump as circulatory support, the patient was transferred to the ICU. After 19 days, the patient was discharged to his home and returned to his previous daily life activities. At 6-month follow-up, the patient was in full vigor with a CPC score of 1. This case highlights the necessity of a chain of activities to rescue a patient. Neither mechanical CPR nor therapeutic hypothermia alone would have had any influence on the final outcome without treatment of the underlying cause: the culprit left main stem coronary occlusion.

Steen S, Sjöberg T, Olsson P, Young M. Treatment of out-of-hospital cardiac arrest with LUCAS, a new device for automatic mechanical compressions and active decompression resuscitation. *Resuscitation*. 2005;67:25-30.
These are the first 100 consecutive pre-hospital patients receiving LUCAS™ 1(V1) CPR in Lund, Sweden. The guidelines from year 2000 were followed, i.e. defibrillate before CPR. The 1-month survival was best in the group of witnessed VF patients; 25%, whereas the survival of non-witnessed cardiac arrest patients was zero. This publication reports on safety aspects of using LUCAS in ambulances. LUCAS did not move on a manikin in a crash test at 30 km/h. The authors recommend that mechanical compressions should be mandatory during transport out of safety reasons.

Halliwell D, Box M. Evaluation of LUCAS by Dorset Ambulance Service. *Br J Resusc*. 2004;3:10-11.
This report describes the experience of introducing LUCAS™ 1(V1) in the ambulance services at Dorset, UK. 43 out-of-hospital patients were treated with LUCAS. 11 had ROSC when arriving to the hospital. The presence of pulses to aid diagnosis was used.

In-Hospital Studies with Control Group

Verstraete S, De Knock J, Müller N, Martens P, Van den Brande F, Vandevelde K. Does the use of LUCAS influence survival for in-hospital cardiac arrest patients? ERC congress 2008. (Poster 240 on file at Physio-Control.)
This is a Belgian retrospective analysis of 73 consecutive in-hospital cardiac arrest patients who got random allocation to either LUCAS™ 1(V1) CPR (N:18) or manual CPR (N:34). 22 patients were excluded from the analysis due to ROSC within 4 minutes (N:16), insufficient data records (N: 4) or too obese to fit LUCAS (N:2). There was no significant difference in ROSC (56% vs. 44%) or hospital discharge (17% vs. 14%) between LUCAS CPR and manual CPR. All patients had a good neurological outcome. There were no major complications reported with the use of LUCAS, and the authors note that the device spares a useful pair of hands during the advanced life-support efforts.

In-Hospital Patient Series and Case Reports

Rudolph S, Barnung S. Case Report: Survival after drowning with cardiac arrest and mild hypothermia. *ISRN Cardiology*. 2011; ID 895625.
This is a Danish case report on a 45 year-old patient who had a cardiac arrest after having winter-swum in icy water and got lost and trapped under the ice. After 20 minutes he was brought up and in asystole. He had 70 minutes of manual CPR on the scene and during transportation, followed by 40 minutes of LUCAS 2 CPR in the hospital, and then the initiation of ECLS (extracorporeal life-support). After 80 minutes on ECLS he regained a spontaneous pulse. The patient was kept in hypothermia and rewarmed after 24 hours. He woke up at day 21 with only smaller deficits and has continued to make progress. The authors discuss the difficulties in judging when a submersion and hypothermic patient is futile based on temperature, and that every link in the chain of survival is key for outcomes.

Bonnemeier H, Simonis G, Olivecrona G, et al. Continuous mechanical chest compression during in-hospital cardiopulmonary resuscitation of patients with pulseless electrical activity. *Resuscitation*. 2011; 82:155-9.
This is an analysis of 28 in-hospital patients that went into PEA due to pulmonary embolism (N: 14), cardiogenic shock/AMI (N:9), severe hyperkalemia (N:2), sustained arrhythmias/electrical storms (N:3). During on average 37.5 minutes (from 10 to 180) of LUCAS™1(V1) compressions the underlying cause were diagnosed and treated with help of CT or PCI or medication. A total of 14 patients (50%) survived of which 13 had no significant neurological deficit. The authors discussed that in six patients that had pulmonary emboli but contraindications to thrombolysis, it was possible that the LUCAS compressions alone were responsible for the thrombus fragmentation. The authors noted that the device bought time and allowed for interventional procedures and treatments. They concluded the device was feasible, safe and might improve outcomes.

Parks J, Waters S, Jennison N. Man or machine? *Resuscitation*. 2010; 81:S64. (Poster on file at Physio-Control.)
This is a report from an emergency department in UK where they have used LUCAS™ 1(V1) during five years and commented on their good experiences and the benefits. There were no reports on any significant injuries by the pathologists. The authors concluded that;

1. Mechanical is better than manual, but manual is better than nothing.
2. In five years' use, our pathologists have not reported any significant injury that may have been caused by LUCAS.
3. LUCAS does not get tired, nor does it stop to stare at the ECG monitor, it is highly effective in providing uninterrupted chest compressions.

Greisen J, Golbækdal K, Mathiassen O, Ravn H. Prolonged mechanical cardiopulmonary resuscitation. (Article in Danish and abstract in English). *Ugeskr Laeger*. 2010;172:3191-3192.
This is a case-report from Denmark on a male patient who was admitted after 55 minutes of out-of-hospital manual CPR which was followed by 45 minutes of in-hospital CPR with LUCAS™ 2. The patient had an angiography during LUCAS CPR, showing no signs of coronary artery disease. During LUCAS CPR the systolic blood pressure was measured to 100 mmHg, and the patient woke up despite the heart was not beating and had to be sedated. Cardiac arrest was found to be due to severe electrolyte disorders with plasma potassium: 2.0 mmol/L and ionized calcium: 0.87 mmol/L. The electrolyte balances were corrected during pacing and anti-arrhythmic therapies. The patient was later discharged without neurological deficits. The authors commented that LUCAS increased vital signs, freed up resources and allowed for other life-saving procedures like setting needles without compromising on CPR quality, and that angiography/plasty could be made despite CPR and cardiac arrest. They concluded that adequate mechanical massage during CPR may improve survival.

Gottignies P, Devriendt J, Ngoc E, Roques S et al. Thrombolysis associated with LUCAS (Lund University Cardiopulmonary Assist System) as treatment of valve thrombosis resulting in cardiac arrest. *Am J Emerg Med*. 2011;29:476.e3-476.e5..
This is a Belgian case report on a 57-year-old patient who arrived in the ED in respiratory distress due to a prosthetic mitral valve thrombosis, which turned into a cardiac arrest. Rescue thrombolysis during ongoing LUCAS™ 1(V1) CPR was initiated and improvement seen after 15 minutes. Patient was discharged from hospital on day 13. The authors speculated that the combination of LUCAS with thrombolysis could have hastened the valve mobility and reduced the arrest time.

Lassnig E, Maurer E, Nömeyer R, Eber B. Osborn waves and incessant ventricular fibrillation during therapeutic hypothermia. *Resuscitation*. 2010;81:500-501.
This is a case report from Austria on a 33-year old ROSC patient who goes into incessant VF during therapeutic hypothermia in the hospital. LUCAS (model unknown, probably LUCAS 1 (V1), is used during 60 minutes and the patient is saved without any neurological deficits. The authors discussed a potential linkage between the Brugada syndrome and a risk for incessant arrhythmia during mild hypothermia.

Elbers P, Craenen A, Driessen A, et al. Imaging the human microcirculation during cardiopulmonary resuscitation in a hypothermic victim of submersion trauma. *Resuscitation*. 2010;81:123-125.
This is a Dutch report on the first use of “sidestream dark field imaging” – a non-invasive way to assess the human (in this case sublingual) microcirculation - during mechanical CPR (LUCAS) in a hypothermic victim of submersion trauma (who did not survive). LUCAS was able to provide microvascular perfusion. The microvascular perfusion was low, improved vastly at ROSC, and was relatively independent from blood pressure. Microcirculation delivers oxygen and nutrients to tissue – the key purpose of CPR.

Simonis G, Ebner B, Strasser R. P93 – Mechanical CPR devices: A useful addition to the resuscitation therapy in the emergency department? (translated from German language: P93 - Mechanische Reanimationshilfen: Eine sinnvolle Ergänzung für die Reanimationsbehandlung auf der Intensivstation?) *Clin Res Cardiol*. 2009;98,Suppl 2:P93.
This German case describes a 58 year-old patient with renal insufficiency and known coronary disease that came in with diffuse chest pain. Tests revealed highly elevated potassium levels and despite immediate glucose–insulin infusion, the patient quickly became hemodynamically unstable, first went into bradycardia, and then into asystole. After a short (2 minutes) period of manual CPR the pneumatic LUCAS™ 1 (V1) chest compression system took over the chest compressions. Glucose-insulin was distributed simultaneously, and an emergency dialysis was provided. After a total of 18 minutes of chest compressions, stable ROSC was achieved.

LUCAS allowed the rescuers, which are otherwise tied to the provision of compressions, to be freed up for other tasks (in this case a quick set up of dialysis, distribution of medication, assistance to establish the venous dialysis access and to manage the arterial pressure measurements). The resuscitation is despite the noise of the CPR device more calm, as the compressions, which when provided manually require a lot of attention, now run automatically. The authors concluded that mechanical CPR devices could be a useful addition to the resuscitation therapy in the emergency room, especially in patients with a potentially reversible cause by resuscitation and during prolonged resuscitation.

Riemann U, Münz S, Maier J, Scheffold N, Hennersdorf M. P06: Life-threatening accidental hypothermia in a 55 year old patient (translated from German language: Lebensbedrohliche akzidentelle Hypothermie bei einer 55jährigen Patientin). *Intensivmedizin und Notfallmedizin*. 2009; 46:261-262
This is a German case report of a 55 year old patient who was found in the snow with accidental hypothermia and refractory VF. After transportation into the hospital, LUCAS CPR was started. Lab tests showed among others an alcohol level of 2.8 promille, and the patient had a temperature of 20,1°C. A triple rewarming therapy was initiated. After 3 h and 15 min of resuscitation with LUCAS CPR, the patient had reached 23,6°C and was successfully defibrillated and a stable ROSC was achieved. Within 11 hours after arrival to the hospital the patient was warmed up to 33 °C and was kept in this therapeutic hypothermia for 24 hours. After 22 days the patient was discharged from the hospital back home without any neurological deficits. The authors concluded that “Nobody is dead unless warm and dead!“ and that also prolonged resuscitations can lead to full patient recovery.

Weise M, Lützner J. Heineck J. P14: Thrombolysis therapy at fulminant pulmonary embolism and a high risk of bleeding – what therapy makes sense? (translated from German language: Lysetherapie bei fulminanter Lungenembolie und hohem Blutungsrisiko – sinnvolle Therapieentscheidung?) *Intensivmedizin und Notfallmedizin*. 2009;46: 264:P14.
This is a German case report on an 83 year-old patient with cardiac arrest due to fulminant pulmonary embolism after a hip surgery. Thombolysis is given, and due to shock, the patient is resuscitated using LUCAS during 45 minutes. After thrombolytic therapy a hemorrhagic shock occurred, but with help of fibrinogen preparations the patient is stabilized and survives and is discharged from hospital. The authors concluded that fulminant pulmonary embolism in combination with a considerably increased risk of bleeding is a medical challenge. Besides the operational/ interventional thrombectomy, the only alternative in principle is the thrombolytic therapy. The then close to obligatory occurring bleeding requires a “planned” preparation.

Friberg H, Rundgren M. Submersion, accidental hypothermia and cardiac arrest, mechanical chest compressions as a bridge to final treatment: a case report. *Scand J Trauma, Resusc Emerg Med*. 2009;17:7.
This is a case-report of an accident in Sweden where three young men were trapped in their car under water at the bottom of a canal and brought up after 21 minutes but in cardiac arrest. The only survivor got early and uninterrupted LUCAS™ 1(V1) chest compressions, which might have made the difference as bridge to final treatment in the hospital. The authors concluded that a mechanical chest compression device facilitated chest compressions during transportation and may be beneficial as a bridge to final treatment in the hospital.

Bonnemeier H, Olivecrona G, Simonis G, et al. Automated continuous chest compression for in-hospital cardiopulmonary resuscitation of patients with pulseless electrical activity: a report of five cases. *Int J Cardiol*. 2009;136:e39-e50.
This study reports five cases of cardiac arrest due to PEA and the benefits of having LUCAS™ 1(V1) device in the in-hospital setting. In all five patients the cardiac arrest was caused either by fulminant pulmonary embolism or by coronary artery occlusion. The article contains interesting LUCAS information; pressure curves, angiographies and ECG recordings. 3 patients survived. The authors concluded that LUCAS significantly improved IHCA resuscitation management and infrastructure and may significantly improve clinical outcome.

Chan L, Wong T, Lau C. Mechanical cardiopulmonary resuscitation device in an accident and emergency department: a case report and literature review. *Hong Kong j. emerg. med*. 2008;15:49-52.
This is a Hong Kong case report of a 38-year-old lady with VF and Brugada syndrome who got prolonged LUCAS™ 1(V1) CPR and finally ROSC but succumbed after 9 days. The role of mechanical CPR is discussed.

Durnez P, Stockman W, Wynendaele R, Germonpre P, Dobbels P. ROSC and neurologic outcome after in-hospital cardiac arrest and LUCAS-CPR. *Resuscitation*. 2008;77S:S49,AP-033. (Poster on file at Physio-Control.)
72 consecutive Belgian in-hospital cardiac arrest patients, of whom 24% had VF, 21% asystole and 56% PEA got treatment with LUCAS™ 1(V1) CPR. ROSC was obtained in 64% (46/72) of the patients. Early neurological outcome (GCS) was favorable in 35% (25/72). 26% (19/72) patients were alive at three and six months follow up with a good neurological outcome (18 patients had CPC1 or 2, only one had CPC 4). Three patients did not fit into LUCAS (4%).

Vatsgar T, Ingebrigtsen O, Fjosea L, Wikstrøm B, Nilsen J, Wik L. Cardiac arrest and resuscitation with an automatic mechanical chest compression device (LUCAS) due to anaphylaxis of a woman receiving caesarean section because of pre-eclampsia. *Resuscitation*. 2006;68:155-159.
This case report from Norway is the first to describe the use of LUCAS™ 1(V1) during resuscitation from cardiac arrest (PEA) caused by anaphylactic shock. A 30-year-old woman received a caesarean section of her 24 week baby because of pre-eclampsia. During the procedure and due to pre-operation medication she fell into an anaphylactic shock. Manual CPR and then LUCAS CPR was provided (during a total of 50 minutes) as a bridge to ROSC. The patient and baby survived without any complications or sequelae at 1 month follow up. During manual chest compressions, it was impossible to measure any intra-arterial blood pressure. When LUCAS chest compressions were started, a pressure of 115/75mmHg was measured in the femoral artery. The authors discussed that by replacing manual CPR with LUCAS elements of fatigue and hands-off intervals were eliminated and a more consistent blood flow could be provided to the heart and brain. CPR in anaphylactic cases may have to be continued for a long time. Mechanical CPR can secure organ perfusion until more sophisticated support is available. Victims of anaphylaxis with circulatory arrest should be seen as potentially resuscitable with a prospect of full recovery if prolonged manual and mechanical CPR, epinephrine and infusion of isotonic solutions are delivered.

Holmström P, Boyd J, Sorsa M, Kuisma M. A case of hypothermic cardiac arrest treated with an external chest compression device (LUCAS) during transport to re-warming. *Resuscitation*. 2005;67:139-141.
This case from Finland describes the rescue of a hypothermic patient with a core temperature of 22.2°C. After unsuccessful initial resuscitation (manual CPR) at the scene, the patient was transported during ongoing LUCAS™ 1 (V1) CPR to the hospital. Good femoral and carotid pulses were noted during the LUCAS compressions. At the hospital, the patient had a cardiopulmonary bypass and after 90 minutes of cardiac arrest, ROSC was achieved. The patient survived with a CPC score of 3. The authors concluded; LUCAS made the transport significantly easier and safer and still allowed good CPR throughout transport. The prolonged use of the LUCAS-device did not cause serious resuscitation related trauma.

Wik L, Kiil S. Use of an automatic chest compression device (LUCAS) as a bridge to establishing cardiopulmonary bypass for a patient with hypothermic cardiac arrest. *Resuscitation*. 2005;66:391-394.
In Norway, a man was found frozen to the ground. Manual CPR was given during transport to the hospital. At the hospital, the patient had an isoelectric ECG and received 1.5 h of LUCAS™ 1(V1) chest compressions until a cardiopulmonary bypass was established. Rapid re-warming followed during which VF was converted to a pulse generating cardiac rhythm. The patient survived with good physical and mental recovery. Mechanical chest compression may be indicated in both hypothermia and intoxication related cardiac arrest. Cardiopulmonary bypass may be the best method for rapid rewarming and preservation of circulation, but it is not available in all hospitals.

Catheterization Laboratory & PCI: Patient Series and Case Reports

Wagner H, Madsen Hardig B, Zughaft D, et al. Physiologic measurements including absolute cerebral tissue oxygen saturation during cardiac arrest. SCCM conference Houston, TX, 2012;E poster 913. (Abstract and poster on file at Physio-Control.)
This is a Swedish patient series for the first time measuring cerebral oxygenation during LUCAS™ 2 chest compressions in prolonged resuscitation cases during PCI in the cath lab. The abstract contains two patient cases and the poster three additional cases. All patients had a technically successful PCI during LUCAS compressions; however, none survived long term. The use of LUCAS produced numerically higher cerebral oxygenation values compared to previously published values on manual chest compressions (average 47% vs. median 29%). The authors discuss that cerebral oximetry might be an indicator of CPR quality and serve as a guide for decision of further treatment like ECMO or IABP.

Azadi N, Niemann J, Thomas J. Coronary imaging and intervention during cardiovascular collapse: Use of the LUCAS mechanical CPR device in the cardiac catheterization laboratory. *Invasive Cardiol*. 2012;24:79-83.
This is a US case series describing the use of LUCAS™ 2 in the cath lab. Four patients experienced sudden cardiac arrest in the setting of acute ST-elevation myocardial infarction (STEMI) and one patient during elective (non-acute, planned) PCI. In all cases it was possible to do the emergency PCI during LUCAS compressions, however only one patient survived. The survivor– who got 15 defibrillations – was discharged home without any neurological sequel. The authors discuss that critically ill patients will likely comprise a larger portion of catheterization laboratory patients in the future and mechanical CPR may prove itself to be an efficient, effective, and practical back up tool. The publication provides angiographic images with LUCAS and a discussion of the benefits and feasibility of coronary angiography and PCI during LUCAS compressions.

Biondi-Zoccai G, Landoni G, Zangrillo A, Agostoni P, Sangiorgi G, Modena M. Use of the LUCAS mechanical chest compression device for percutaneous coronary intervention during cardiac arrest: is it really a game changer? HSR Proceedings in *Intensive Care and Cardiovascular Anesthesia*. 2011;3:203-205.
This is a case describing a 40 yr old patient that came into the ED with a suspected myocardial infarction that turned into VF and after successful defibrillation into a PEA. Under manual CPR the patient was transferred to another hub care center ED for further care. In this hospital LUCAS™ 2 was applied and the patient transported to cath lab where a technically successful PCI was done during LUCAS compressions. Despite the successful PCI, no ROSC was achieved and after further 30 minutes of CPR the resuscitation was terminated. The authors discuss that more data is still needed and that LUCAS should best be reserved for patients with cardiac arrest without an ominous prognosis per se.

Gillis M. Full neurological recovery following cardiac arrest during percutaneous coronary intervention due to accidentally intracoronary administration of ajmaline. *Resuscitation*. 2011;82:1254.
This is a case of an erroneous injection of medication during a planned PCI in a 58-year old man which resulted in VF, which after a series of shocks turned into asystole. LUCAS was applied and used together with the Boussignac tube, and overdrive pacing was provided, and after 130 min of CPR and neutralizing medication, the patient got ROSC. Post-resuscitation cooling was provided, and on day 6 the patient returned home with good neurological outcome. One month after, the patient came back for the planned PCI, which was done successfully.

Wagner H, Hardig B, Harnek J, Götberg M, Olivecrona G. Monitoring possibilities of resuscitation efforts during cath lab resuscitation. *Resuscitation*. 2010;81:S50. (Poster on file at Physio-Control.)
This is a single case report where hemodynamic measurements, ETCO2 and SpO2 saturation were recorded continuously during the whole cardiac arrest event. LUCAS™ 1(V2) maintained circulation during 52 minutes of resuscitation and PCI and during 10 minutes after ROSC. It showed how injection of epinephrine influenced flow and oxygen saturation. It confirmed that LUCAS could produce and maintain circulation for up to at least one hour with good neurologic outcome. LUCAS produced significantly higher systolic and mean AP, and significantly lower diastolic AP compared to manual chest compressions.

Wagner H, Madsen Hardig B, Harnek J, Götberg M, Olivecrona GK. Abstract 91: Aspects on resuscitation in the coronary interventional catheter laboratory. *Circulation*. 2010;122:A91. (Poster on file at Physio-Control.)
This is an analysis of vital physiological parameters during resuscitation efforts collected by a cath lab monitoring system during manual and LUCAS™ 1(V2) chest compressions in 10 cardiac arrest patients. The patients were mainly acute STEMI (acute ST-elevation myocardial infarction) patients and required lengthy resuscitation of an average of 45 + 23 minutes. LUCAS created higher systolic and mean arterial blood pressures (103 ±33 and 46 ±17) vs. manual CPR (48 ± 10 and 32 ±6 mmHg). CPP fluctuated widely over the resuscitation time, and increased at infusion of adrenalin. However, adrenalin decreased $EtCO_2$ and SpO_2. 9/10 patients had a successful PCI, 50% survived between 0.5 and 13 days and 20% were discharged with good neurological outcome. The authors concluded that mechanical chest compressions could maintain circulation for extended periods of time during cardiac arrest in the cath-lab.

Larsen A, Hjörnevik Å, Bonarjee V, Barvik S, Melberg T, Nilsen D. Coronary blood flow and perfusion pressure during coronary angiography in patients with ongoing mechanical chest compression: A report on 6 cases. *Resuscitation*. 2010;81:493–497.
This publication investigates the relationship between coronary perfusion pressure and TIMI flow (flow visualized by coronary angiography) in six Norwegian patients who got LUCAS CPR (1 V1) and had a simultaneous coronary angiography. The duration of resuscitation was between 30 to 150 minutes. In 4 out of 6 patients there was a satisfactory coronary artery perfusion pressure (measured invasively) and TIMI grade 3 flow (normal) on coronary angiography. Two of the six patients survived the first 24 h. Two patients did not have a satisfactory perfusion pressure and adequate flow rate was not seen. This case series showed that the LUCAS device was capable of producing a coronary perfusion pressure above 15mmHg at least in some patients, which was associated with TIMI3 flow as demonstrated with coronary angiography. In the discussion part the importance of correct positioning of the LUCAS device in the middle of the chest to ensure flow is highlighted.

Wagner H, Terkelsen, C, Friberg H, et al. Cardiac arrest in the catheterization laboratory: a 5-year experience of using mechanical chest compressions to facilitate PCI during prolonged resuscitation efforts. *Resuscitation*. 2010;81(4): 383-387.
This is a Swedish retrospective study of the use of LUCAS 1 (V1 and V2) over five years, in mainly STEMI (acute ST-elevation myocardial infarction) patients who arrived alive to the cath lab but required lengthy resuscitation with LUCAS CPR during continued coronary angiography/intervention. 33 STEMI patients (out of a total 3,058) required LUCAS CPR, indicating an incidence of prolonged cath lab resuscitations of 10.8 per 1000 STEMI procedures. Additional 10 patients; 7 NSTEMI, 2 elective and 1 patient with tamponade, required LUCAS CPR, resulting in a total of 43 patients during the five years. Of these 43 patients, 12 patients were discharged alive from the hospital, 11 with good neurological outcome (CPC 1). The one who did not have a good outcome died in a referral hospital due to anoxic brain injury; this was one of the earliest patients for whom LUCAS was applied very late. Survival rate in this high-risk group of patients thus was ~25%. The mean treatment time was 28.15 minutes (1-90 minutes), and for the survivors the mean treatment time was 16.5 minutes (1-50 minutes). In the majority of cases the "culprit artery" was the LAD or Left Main coronary artery. 65% of the patients had PEA as the initial rhythm. LUCAS was compatible for use with most fluoroscopy projection angles except the straight anterior posterior angle. Fortunately, the available views are almost always the preferred angiographic views during PCIs even without LUCAS. It is concluded that it is unlikely that few, if any, of these patients would have survived without the use of LUCAS.

Jakob A, Rittger H, Holzmann S, Brachmann J, Sinh A. The external chest compression system LUCAS enables angiographic procedure at primary non-shockable ventricular fibrillation (translated from German language: P337-Das externe Thoraxkompressionssystem LUCAS ermöglicht die Durchführung einer Herzkatheteruntersuchung bei primär nicht defibrillierbarem Kammerflimmern.) *Clin Res Cardiol*. 2009; 98, Suppl 2;P337. Abstract.
This is a German case-report of an 85 year-old patient who arrived to the hospital in cardiogenic shock and with clinical signs of an acute anterior myocardial infarction. The patient had stopped long-term anti-thrombotic medication due to a hip replacement surgery. On the way to the cath lab, the patient went into refractory VF. LUCAS was applied and a coronary angiography revealed an occluded stent in the LAD. After successful recanalization the VF could successfully be converted, and together with the distribution of catecholamines and the insertion of an intra-aortic balloon pump, the patient became hemodynamically stable. The authors concluded that automated external chest compression systems could alone sustain a sufficient temporary blood circulation in cases of intractable disorders of the heart rhythm. This enables therapies, in particular coronary interventions in the cath labs during ongoing resuscitation that can stabilize and save the patient.

Hödl R, Maier R, Stoschitzky, Lischnig M, Perl S, Luha O. A case of complicated transcatheter aortic valve implantation (TAVI). *Journal für Kardiologie*. 2009;16:189. Abstract 167. (Austrian Journal of Cardiology: available at www.kup.at/kup/pdf/7899.pdf)
This is an Austrian cath lab case report of a 82 year old patient who was treated for a severe aortic valve stenosis with balloon valvuloplasty. When the balloon was deflated, the patient went into hemodynamic shock. CPR was started, followed by application of LUCAS™ 1(V1). Coronary arteries were open, but aortic root angiogram revealed severe aortic valve regurgitation as a functional cause of the cardiac arrest. An aortic valve prosthesis was inserted during ongoing CPR conditions. After 20 minutes of cardiac arrest and a successful insertion of the new valve, the patient got ROSC. The patient was discharged from ICU after five days with an excellent function of the valve prosthesis, and recovered completely without any sequel. The authors concluded that severe complications may occur during TAVIs and therefore a mechanical chest compression device should be available to improve both quality of chest compressions and patients' clinical outcome.

This case was also presented at PCR09 and awarded as top three challenging cases.

Berggren K, Zughaft D. The use of mechanical chest compressions in the cath lab during PCI treatment in patients with cardiac arrest from a nursing perspective. *PCR 2009*. No13. A0227 p.8. Abstract. (Available at Physio-Control on request.)
The following algorithm for use of LUCAS mechanical CPR in the cath lab in Lund, Sweden has been developed: begin manual CPR, apply LUCAS and start mechanical chest compressions, intubate patient, diagnose the cause of the arrest; if myocardial rupture, stop resuscitation, in remaining patients; continue intervention during LUCAS CPR. After successful intervention, stop LUCAS CPR, check circulation and defibrillate if necessary. If no ROSC, consider left ventricular assist device or maintain LUCAS CPR for 30 minutes before stopping.

Cornelis K, Agostoni P, Vermeersch P, Van Langenhove G, Van den Branden F. Use of an automatic mechanical chest compression device for cardiopulmonary resuscitation during percutaneous coronary interventions. ERC congress 2008. Poster 150. (Poster on file at Physio-Control.)
This Belgian study reports on five patients who were treated with PCI during LUCAS™ 1(V1) compressions. Two were stable, elective patients in whom the arrest occurred during the procedure. These two patients recovered completely. A third patient became unstable and went into cardiac arrest after recent PCI, got renewed PCI treatment, but did however not survive. Additionally, two pre-hospital patients were referred to the cath lab from the ER with ongoing LUCAS CPR, got successfully treated with PCI, but did not survive. The authors concluded that it is feasible to use LUCAS CPR during PCI. In particular, the device can be life-saving during elective PCI that become complicated because of acute events.

Larsen A, Hjornevik A, Ellingsen C, Nilsen D. Cardiac arrest with continuous mechanical chest compression during percutaneous coronary intervention. A report on the use of the LUCAS device. *Resuscitation*. 2007;75:454-459.
Norwegian cardiac arrest patients (N: 13) from both out-of-hospital as well as in-hospital were transported to and treated in the cath lab during ongoing LUCAS compressions. The mean LUCAS™1(V1) compression time was long; 105±60 minutes (range 45—240 minutes). Angiography and eventually PCI was possible in all cases during ongoing LUCAS chest compressions. There were no practical problems with regard to LUCAS application or ventilation. The mean systolic and diastolic blood pressure obtained by LUCAS was 81±23 and 34±21 mmHg, respectively. Three patients survived the procedure, but no one was discharged alive. Autopsies were performed in 11 patients and showed no life-threatening or unexpected injuries despite the long resuscitation attempt. Manual CPR would have been almost impossible and could not have been extended for a prolonged period. LUCAS was considered well suited for use in the cath lab and ensured an adequate systemic blood pressure in most patients without life-threatening injuries.

Grogaard H, Wik L, Eriksen M, Brekke M, Sunde K. Continuous mechanical chest compressions during cardiac arrest to facilitate restoration of coronary circulation with percutaneous coronary intervention. *J Am Coll Cardiol*. 2007;50:1093-1094.
These Norwegian authors report on two cardiac arrest cases patients receiving LUCAS™ 1(V1) CPR during PCI. Moreover, the applicability of performing PCI during uninterrupted LUCAS chest compressions in a methodological pig study (N: 5) is evaluated. It was concluded that LUCAS enabled adequate hemodynamics as well as angiography and PCI in both humans and pigs. The coronary arteries were visualized despite the fact that LUCAS occupies the space above the middle of the chest allowing only for oblique angiographic projections. The first case describes a pre-hospital patient with a therapy resistant cardiac arrest that arrived in the emergency department with ongoing LUCAS compressions. Due to a delay in the decision to transport the patient to the cath lab, the patient was revascularized first after 110 minutes of cardiac arrest. Circulation was maintained by LUCAS only, and 6 hours after the cardiac arrest, LUCAS was discontinued and the patient died. The second case was a patient who had received a successful PCI. Immediately afterwards she collapsed with PEA. After ten minutes of manual CPR, VF and failed defibrillation attempts, LUCAS compressions were initiated. A control angiogram showed reduced coronary flow, which was followed by PCI and increased medication. After 70 minutes with LUCAS and a successful revascularisation, stable ROSC was achieved. This patient recovered fully neurologically intact and has today a 100% working capacity. The authors concluded that LUCAS CPR may be an alternative approach for at least two circumstances:

1. Cardiac arrest occurring during the PCI procedure.
2. Other cardiac arrests with suspicion of MI, if the patient can be brought within a short time to the angiographic laboratory with uninterrupted mechanical chest compressions.

Schäfer K, Flemming K. Resuscitation with LUCAS – a case report. (Translated from German language Reanimationsbehandlung mittels LUCAS – ein Fallbericht.) *Clin Res Cardiol*. 2007:96(Suppl 1)P961.
This is a case reported from Dresden, Germany. The cardiac arrest patient was found in the hospital stairways. The patient was defibrillated but stable ROSC was not achieved due to refractory VF. The ECG revealed ST-elevation and the patient was transported with ongoing LUCAS compressions to the cath lab. The right coronary artery was stented during LUCAS™ 1(V1) CPR, the coronary blood flow restored and ROSC achieved. Despite 60 minutes of LUCAS CPR and several parameters indicating a poor prognosis, the patient was fully recovered with a very good neurological status and left the hospital after two weeks of care. The authors concluded that LUCAS CPR enabled a fast intervention of an occluded coronary artery also during instable circulation, and allowed for a shortening of the door-to-balloon time.

Agostoni P, Cornelis K, Vermeersch P. Successful percutaneous treatment of an intraprocedural left main stent thrombosis with the support of an automatic mechanical chest compression device. *Int J Cardiol*. 2008;124:e19-e21.
This case study describes a PCI procedure on a patient who suddenly goes into cardiac arrest on the cath lab table in Belgium. The patient was initially successfully stented with a drug-eluting stent in one of the large coronary arteries (LAD). However, after five minutes the patient suddenly experienced a hemodynamic collapse. Manual CPR was provided and a control angiogram showed a total occlusion of the stented artery. LUCAS™1(V1) CPR was initiated and the blood pressure rose to 90/40mmHg while more medication was given and the patient was intubated. During ongoing LUCAS CPR, during which the patient had episodes of VF, PEA and asystole, the coronary artery flow was restored by ballooning and stenting. A temporary pacemaker and an intra-aortic balloon pump were placed, and the patient hemodynamically stabilized and moved to the intensive care unit. After progressive improvement she was discharged back to the referral hospital in stable conditions.

The authors discussed that urgent need for CPR is difficult to handle in the cath lab due to the gantry around the patient and the height of the table. Furthermore no additional PCI can be done during efficient manual CPR due to hindrance and high radiation exposure for the personnel performing CPR. This case shows that a PCI procedure can be carried out successfully during ongoing LUCAS compressions, which provides an efficient circulatory pulsatile support (as shown by the pressure curves recorded for both manual and LUCAS CPR in this case) without the need for additional staff involved in basic life support.

Olivecrona G, Bondesson P. Mechanical chest compressions in a patient with left main closure during PCI. Case of the week October 23, 2006. www.tctmd.com. Accessed March 28, 2012.
This is a Swedish case report of a patient that, during a planned PCI procedure, suddenly developed thrombi that resulted in a total occlusion of the left main coronary artery. The patient went into VF and was defibrillated twice unsuccessfully. Manual compressions were started until LUCAS™ 1(V1) was applied. The procedure was continued with the aim to reopen the left main artery and the anti-thrombotic medication was increased. Flow was re-established 20 minutes following the initiation of LUCAS support. The patient was successfully defibrillated to sinus rhythm. Because of initial low systolic blood pressure (65mmHg systolic) LUCAS support was continued for another 10 minutes despite sinus rhythm. An intra aortic balloon pump was inserted, and LUCAS stopped when the patient reached a systolic blood pressure of 95 mmHg. The next day the patient was fully awake and in good vigor. Four weeks after the procedure, the patient was alive and doing well. The authors conclude that LUCAS did not hinder continuation of the PCI procedure to restore coronary blood flow. The mood in the cath lab was calm at all times despite the ongoing VF since the patient's circulation was maintained with LUCAS. This is quite contrary to what usually happens in such situation when manual compressions are used. The LUCAS can be a useful tool in the cath lab during situations of acute vessel closure causing cardiac arrest.

Linder R, Wennersten G. Mechanical compression during PCI saved life. (Translated from Swedish language Mekanisk kompression under perkutan koronarintervention räddade liv.) *Lakartidningen* (journal of Swedish physicians' association). 2006;34:2390-2392.
This is a Swedish case where an acute myocardial infarction turned into a cardiac arrest in the Emergency Department (ED) and LUCAS™ 1(V1) was used before, during and after PCI, and despite sinus rhythm. A 57-year old female came into the hospital with an acute myocardial infarction which converted into a therapy resistant VF. After 25 minutes with LUCAS compressions in the ED she was successfully defibrillated but still in cardiogenic shock, why LUCAS compressions were continued to secure blood flow to the brain. Despite bad prognosis, she was transported to the cath lab where an angiogram showed an occluded coronary artery (LAD). During ongoing LUCAS CPR, the coronary blood flow was restored with PCI. She experienced a reperfusion arrhythmia which was quickly converted to sinus rhythm at the first shock. After five more minutes with LUCAS, the systolic blood pressure reached 125/70mm Hg and LUCAS was discontinued. She recovered without cerebral or cardiac abnormalities. The second day, she complained about thoracic pain due to the CPR, however, two weeks later, the patient was full of lust for life, had stopped smoking, and considered herself having got a second chance in life.

SAFETY STUDIES

Safety Trials with Control Group

Menzies D, Barton D, Nolan N. Does the LUCAS device increase injury during CPR? *Resuscitation*. 2010; 81S:S20,AS076. Abstract.
This Irish study compared post-mortem findings on patients receiving manual CPR in combination with LUCAS™ 1 (V1) CPR (N: 40) at the Emergency Department in one hospital with the findings from patients receiving manual CPR alone (N:39) in the Emergency Department in another hospital. Rib fractures were present in 13/40 (32,5%) patients in the LUCAS group and 19/39 (48,7%) in the manual group (p=0.142). Sternal fractures were present in 9/40 (22,5%) patients in the LUCAS group and 16/39 (41%) in the manual group (p=0.144).The mean number of rib fractures was 1.84 in the LUCAS group and 3.21 in the manual group (p=0.096). The authors concluded that they could not identify a significant variation in trauma with the use of the LUCAS compared to manual CPR. This author presented interim data from the same study at the ERC congress in 2008. Menzies D, Barton D, Darcy C, Nolan N. Does the LUCAS device increase trauma during CPR? *Resuscitation*. 2008;77S:S13, AS-034.

Truhlar A, Hejna P, Zabka L, Zatopkova L, Cerny V. Injuries caused by the AutoPulse and the LUCAS II resuscitation systems compared to manual chest compressions. *Resuscitation.* 2010;81S:S62, AP110.
This Czech prospective study compared injuries caused by the AutoPulse (Zoll, USA), LUCAS II (Jolife, Sweden), and manual CPR in both survivors and non-survivors of out-of-hospital cardiac arrest (OHCA). The survivors underwent physical examination and a thoracic X-ray, non-survivors were autopsied. CPR was attempted in thirty patients: A-CPR 8, L-CPR 11, and M-CPR 11. Injuries were observed in 7/8 (87.5%) in A-CPR, 8/11 (72.7%) in L-CPR, and 3/11 (27.3%) in M-CPR group (P = 0.02). Sternal fractures were present in 3/8, 4/11, and 1/11 (P = 0.33), multiple rib fractures (≥3) in 4/8, 6/11, and 2/11 (P = 0.25), and mediastinal haematomas in 5/8, 2/11, and 0/11 patients (P = 0.003). Pericardial effusions (2 pts.) and adventitial aortic haematomas (4 pts.) were observed in A-CPR group only (P = 0.06 and 0.002). There were 1/8 (12.5%), 1/11 (9.1%), and 4/11 (36.4%) patients discharged from hospital [CPC 1–2] (P = 0.33). Preliminary results of this study are limited by its size and prior BLS (90.0%) whose complications are difficult to separate from device associated injuries.

Xanthos T, Pantazopoulos I, Roumelioti H, et al. A comparison of autopsy detected injuries in a porcine model of cardiac arrest treated with either manual or mechanical chest compressions. *Eur J Emerg Med*. 2011;18:108-110.
This is a Greek retrospective, experimental autopsy study that compared complications after approx. 16 minutes of CPR with manual technique vs. LUCAS™ 1(V1), in pigs (N:53+53). There were significantly fewer injuries in the LUCAS group compared to the manual group (p=0.004). The manual CPR was performed by qualified rescuers alternating every 2 minutes and according to guidelines. The authors conclude that LUCAS minimized the resuscitation-related trauma compared to manual CPR in this swine study.

Smekal D, Johansson J, Huzevka T, Rubertsson S. No difference in autopsy detected injuries in cardiac arrest patients treated with manual chest compressions compared with mechanical compressions with the LUCAS™ device – a pilot study. *Resuscitation*. 2009;80:1104-1107.
This is a Swedish prospective, controlled autopsy study on 85 patients not surviving cardiac arrest. The majority of patients were pre-hospital cardiac arrest patients randomized to either LUCAS™ 1(V1) CPR (N: 38) or manual CPR (N: 47). All patients got a few minutes of manual CPR before randomization. Autopsy showed no injuries at all in 42.1% of the patients in the LUCAS group and 55.3% in the manual CPR group (n.s., p = 0.28). The incidence and type of injuries from CPR were not significantly different between the two groups and none of the CPR-related injuries were considered to be life-threatening. Multiple rib fractures (more than three) were present in 17/38 (44.7%) of the patients in the LUCAS group and 13/47 (27.7%) in the manual group (n.s., p = 0.12). Sternal fractures were present in 29.0% in the LUCAS group compared to 21.3% in the manual group (n.s, p = 0.46). The authors concluded that LUCAS seemed to be associated with the same incidence and variety of injuries as manual CPR.

Safety Patient Series

Oberladstaetter D, Braun P, Freund M, Rabl W, Paal P, Baubin M. Autopsy is more sensitive than computed tomography in detection of LUCAS-CPR related non-dislocated chest fractures. *Resuscitation*. 2012; 83:e89-e90. (presented at ERC congress 2008. *Resuscitation*. 2008; 77S: S51, AS-039; Thorax injuries after CPR. (Poster 039 on file at Physio-Control.)
This is an Austrian prospective, blinded study comparing computer tomography (CT) and autopsy findings with the purpose to determine the frequency of thorax injuries after one minute of LUCAS™1(V1) CPR on 13 fresh, female corpses for whom autopsy was planned. Exclusion: trauma, surgery, CPR or lack of consent. One minute of LUCAS CPR was given on each corpse. Autopsy showed that 9/13 had sternum fractures and 10/13 had rib fractures. All fractures were classified as minor and non-dislocated. No lesions of the inner organs could be detected. None of the lesions were visible in a CT scan. The authors compare the results with previous studies on the manual ACD CardioPump, and speculate that LUCAS caused less injuries due to a better positioning and a refined active decompression technique. The authors concluded that one minute of LUCAS CPR caused only minor lesions and non-dislocated fractures on sternum and ribs in fresh, female cadavers. They also concluded that autopsy was more sensitive to detect chest fractures compared to CT.

Englund E, Silfverstolpe J, Halvarsson B L. Injuries after cardiopulmonary resuscitation: A comparison between LUCAS mechanical CPR and standard CPR. *Resuscitation*. 2008;77S: S13, AS-036. Abstract.
This is an analysis of injuries found at autopsy of 200 LUCAS™ 1(V1) non-survivors and on 21 manual CPR non-survivors in Lund, Sweden. Sternal fractures were found in 65% of the LUCAS cases and in 28% of the manual CPR cases. Rib fractures were found in 92.5% of the LUCAS cases and 52% of the CPR cases. Hemothorax and liver capsule rifts were also seen in the LUCAS group. In non-survivors of cardiac arrest injuries found at autopsy were more common following LUCAS CPR when compared to standard CPR.

Bonnemeier H, Gerling I, Barantke M, Schunkert H. Necropsy findings of non-survivors of CPR after mechanical and conventional chest compression. ERC congress 2008. (Poster 470 on file at Physio-Control.)
This is a German autopsy study on 64 consecutive non-survivors of cardiac arrest, of which 57 received manual CPR and 7 received manual as well as LUCAS™ 1(V1) CPR (from 15 minutes up to 80 minutes). 85% of the patients had rib fractures, 19% had sternum fractures, 44% had minor tissue injuries and 23% had insignificant hematomas (<50ml). There were no life-threatening CPR-related injuries. There was a trend to less injury following LUCAS CPR: 43% (3 pts.) had rib fractures, no sternal fractures were found, 29% (2 pts.) had tissue injuries and 29% (2 pts.) had hematomas. The authors concluded that mechanical compressions did not cause more serious complications than manual CPR. They also concluded that LUCAS was safe, feasible, and when correctly used and applied, it may assist in significantly improving the care and outcome of cardiac arrest patients.

ORGAN DONATION STUDIES

Organ donation trials with Control Group

Carmona F, Ruiz A, Palma P, et al. Effect of implantation of a mechanic chest compressor (LUCAS) in organs perfusion and transplant rate from donors after cardiac death (DCD) Maastricht type II. *Resuscitation*. 2010;81S:S22,AS082.
This is a prospective and comparative study during January 2006 to January 2010 on LUCAS™ 1(V1) (N: 94) vs. manual chest compressions (N: 118) during transportation of potential organ donors (N total: 212) after cardiac death in Barcelona, Spain. 36.2% (34/94) and 33.9% (40/118) in the LUCAS and manual groups respectively became real donors. On average 2.73 (LUCAS group) and 2.65 organs (manual group) per donor were harvested (n.s., p= 0.19). Rejected kidneys were discarded due to poor perfusion in 47% of the LUCAS group and 74% of the manual group. The authors concluded that LUCAS was at least as effective as manual CPR with a trend to increase the numbers who became real donors, kidney procurement as well as transplant rate. A significant decrease of the percentage of rejected kidneys by poor perfusion was observed in the LUCAS group.

Mateos-Rodriguez A, Pardillos-Ferrer L, Navalpotro-Pascual J, Barba-Alonso C, Marin-Maldonado M, Andres-Belmonte A. Short communication: Kidney transplant function using organs from non-heart-beating donors maintained by mechanical chest compressions. *Resuscitation*. 2010;81:904-907.
This Spanish retrospective, observational study investigated if mechanical CPR in non-heart beating donors would give a lower failure rate of transplanted kidneys in recipients of organs, compared to manual CPR. Both AutoPulse and LUCAS™1(V1) were used in the mechanical group. No significant difference could be found. A note; three patients achieved successful ROSC in the mechanical chest compression group after initiation of the non-heart beating donor protocol, of which one with good neurological recovery. In another abstract from ERC 2010 (Mateos-Rodriguez A, Navalpotro-Pascual J, Pardillos-Ferrer L, Marin-Maldonado M. Cardiac life mechanical support in extrahospitalary donors after cardiac death. Resuscitation. 2010;81S:S22, AS082) the authors concluded that the use of the mechanical devices joined perfectly the non-beating heart donors procedure. The quality improved CPR and facilitated the work of the emergency team.

EXPERIMENTAL DATA ON LUCAS

In addition to the below experimental studies evaluating different aspects of the efficacy and safety of LUCAS, there is a wide range of experimental study publications where LUCAS has been used to provide standardized chest compressions while evaluating and comparing other resuscitation therapies. These studies are not included in this overview.

Wagner H, Madsen Hardig B, Steen S, Sjoberg T, Harnek J, Olivecrona GK. Evaluation of coronary blood flow velocity during cardiac arrest with circulation maintained through mechanical chest compressions in a porcine model. *BMC Cardiovasc Disord*. 2011;11:73.
This experimental study from Sweden studied the correlation between peak coronary flow velocity (APV) as measured by Doppler, and the coronary perfusion pressure (CPP) during LUCAS™2 chest compressions. 11 pigs got VF induced during one minute and then 20 minutes of LUCAS chest compressions before first defibrillation. No epinephrine was administered before the first defibrillation. 9/11 pigs got ROSC. There was a significant correlation between CPP and APV during LUCAS compressions. APV (flow velocity) was equal or higher with LUCAS compressions compared to baseline (normal flow) before VF was induced in the pigs. CPP was maintained at greater than 20mmHg during LUCAS compressions. The authors concluded that LUCAS can sustain and reestablish coronary blood flow in non-diseased coronary arteries during cardiac arrest. They also noted that this is in line with the more subjective visual coronary artery flow (TIMI III) that has previously been documented for LUCAS during extensive periods of resuscitations in humans.

Menegazzi J, Salcido D, Housler G, Logue E. Feasibility of initiating extracorporeal life support during mechanical chest compression CPR: A porcine pilot study. *Resuscitation*. 2012;83:130-133.
This study made in Pittsburgh, PA, evaluates the feasibility of installing a portable cardio-pulmonary bypass (CPB) circuit during LUCAS™ 1(V2) compressions in five pigs. After 8 minutes of VF, LUCAS was started and five minutes later the installation of the CPB was initiated. After a total of 17-30 minutes of LUCAS CPR, the CPB was successfully installed in all five animals and took over circulation support and continued until ECG indicated a shockable rhythm. First rescue shocks were given at 22, 32, 35, 44, and 65 minutes respectively. It was necessary to briefly discontinue chest compressions only during the most delicate part of inserting the catheters into the vessels. Only the 65-minute animal did not attain ROSC. The authors conclude that mechanical chest compression may be a suitable therapeutic bridge to the installation of CPB and does not interfere with CPB catheter placement

This study was published in abstract format in 2009: Menegazzi J, Salcido D, Logue E. Feasibility of Initiating Cardiopulmonary Bypass During Mechanical Chest Compression CPR". *Circulation*. 2009;120:S1456 Abstract P69.

Xhantos T, Pantazopoulos I, Roumelioti H, et al. A comparison of autopsy detected injuries in a porcine model of cardiac arrest treated with either manual or mechanical chest compressions. *Eur J Emerg Med*. 2011;18:108-110.
This is a Greek retrospective, experimental autopsy study that compared complications after ~16 min CPR with manual technique vs. LUCAS™1(V1), in pigs (N: 53+53). There were significantly fewer injuries in the LUCAS group compared to the manual group (p=0.004). The manual CPR was performed by qualified rescuers alternating every 2 min and according to guidelines. The authors conclude that LUCAS minimized the resuscitation-related trauma compared to manual CPR in this swine study.

Weng Y, Chung S, Park J, et al. Comparison of the effect of 2 mechanical chest compressors on coronary perfusion pressure and outcomes of CPR with selective head cooling. *Circulation*. 2010;122:A179. Abstract.
This experimental study (N:10) evaluated the effect of LUCAS™ 1(V1) vs. Thumper CPR, both in combination with selective head cooling (RhinoChill). VF was induced and left untreated for 10 minutes, then 5 minutes of mechanical CPR with provision of epinephrine after 2 minutes of compression. LUCAS achieved significantly higher CPPs and better ROSC rates after the first defibrillation (100% vs. 40%, $p<0.05$) compared with the Thumper group. The authors concluded that LUCAS device produced a more effective chest compression than the Thumper. (Comparative CPP curves are depicted in the abstract; it shows LUCAS CPP of ~20-30mmHg and Thumper CPP of ~10-20 mmHg without epinephrine and after injection of epinephrine ~30-60 and ~15-25mmHg respectively.)

Weng Y, Chung S, Park J, et. Comparison of the effect of 2 mechanical chest compressors on coronary perfusion pressure and resuscitation outcomes during CPR. *Circulation*. 2010;122:A180. Abstract.
This experimental study (N:9) evaluated the effect of LUCAS™ 1(V1) (N:4) vs. Thumper CPR (N:5). VF was induced and left untreated for 10 minutes, then 5 minutes of mechanical CPR with provision of epinephrine after 2 minutes of compression. LUCAS achieved significantly higher CPPs and better ROSC rates after the first defibrillation (100% vs. 60%, p<0.05) compared with the Thumper group. A significantly reduced incidence of recurrent VF within 10 minutes after ROSC (0.25+0.50 vs 17.80+5.50, p<0.05) was observed in animals treated with LUCAS CPR. The authors concluded that LUCAS device produced a more effective chest compression than the Thumper. (Comparative CPP curves are depicted in the abstract, it shows LUCAS CPP of ~20-30mmHg and Thumper CPP of ~10-20 mmHg without epinephrine and after injection of epinephrine ~35-55 and ~18-25mmHg respectively.)

Liao Q, Sjöberg T, Paskevicius A, Wohlfart B, Steen S. Manual versus mechanical cardiopulmonary resuscitation. An experimental study in pigs. *BMC Cardiovas Disord*. 2010;10:53. (open access: www.biomedcentral.com/1471-2261/10/53).
This Swedish experimental study on 16 pigs evaluated the LUCAS™ 1(V2) (N:8) compared to manual CPR (N:8) according to guidelines 2005 provided by 16 trained paramedics, who took turns every two minutes and had a metronome to help keep an accurate rate. After 5 minutes of induced VF, CPR was provided during 20 minutes, then defibrillation was given. LUCAS CPR resulted in improved hemodynamics and ROSC vs. manual CPR (CPP 20mmHg vs. 5 mmHg (P<0.01), $EtCO_2$ 3.4 kPa vs. 2.2 kPa, ROSC 8/8 vs. 3/8 pigs) There were also less rib fractures with LUCAS vs. manual CPR. The authors concluded that LUCAS was significantly more efficient and gave less injury than manual CPR in this porcine model.

Fontanals J, Carretero M, Arguis M, Martinez-Ocon J, Ruiz A. Lung injury secondary to resuscitation using mechanical external chest compression devices (LUCAS vs. AutoPulse). Histopathology study: 13AP2-4. *Eur J of Anaesthesiol*. 2010;47:191. (open access; http://journals.lww.com/ejanaesthesiology/Fulltext/2010/06121/Lung_injury_secondary_to_resuscitation_using.611.aspx)
This Spanish experimental study on 24 pigs compared the LUCAS™ 1(V1) and AutoPulse (ZOLL®) chest compression systems with regards to cardiac output (CO) and lung injury. There were no statistical difference in MAP comparing both methods, but there was statistical significant difference (p<0,05) in the CO generated being higher using LUCAS versus AutoPulse (0,636±0,061 mmHg vs. 0,399±0,038 mmHg). They did not find any differences between the two different chest compression devices with regards to lung injury.

Carretero M, Fontanals J, Agusti M, et al. Monitoring in resuscitation: Comparison of cardiac output measurement between pulmonary artery catheter and NICO. *Resuscitation*. 2010;81:404-409.
This Spanish experimental study on 24 pigs evaluated the accuracy of the non-invasive NICO method to assess the cardiac output, compared to invasive thermodilution. Even if not designed to compare LUCAS™1(V1) and AutoPulse, it utilized both methods for CPR to ensure that the different mechanisms of compression did not interfere with the measurement of cardiac output. The cardiac output figures were consistently higher for LUCAS.

Response by Halperin H, Paradis N, (Resuscitation 2010, EPub August) noted that a porcine-specific model of AutoPulse has to be used to appropriately evaluate LDB-CPR in animals, and therefore the data in this study should not be misinterpreted to reflect the hemodynamics of AutoPulse in humans.

Matsuura T, McKnite S, Metzger A, Yannopoulos D, Aufderheide T, Lurie K. An impedance threshold compression-decompression CPR device (LUCAS) improves chances for survival in pigs in cardiac arrest. *Circulation*. 2008;118:S1449-S1450.
This study made in Minneapolis, MN, US, evaluates the efficacy and safety of an active vs. a non-active (sham) impedance threshold device (ITD) (ResQPod, Adv. Circulatory Systems Inc.) on pigs who all received LUCAS™ 1(V1) CPR. There were no differences in hemodynamic values with or without the active ITD. The endotracheal pressure was significantly higher with the active ITD (active ITD = -2.0 ±0.5 vs. sham ITD = -0.2 ±0.5, P <0.01) than the non-active ITD. ROSC was achieved with fewer shocks in the active ITD group. These positive findings and lack of any adverse outcomes as shown in autopsy support the safety and efficacy of combining ITD with LUCAS.

Walcott P, Melnick S, Banville I, Chapman F, Killingsworth C, Ideker R. Pauses for defibrillation not necessary during mechanical chest compressions during pre-hospital cardiac arrest. *Circulation*. 2007;116:II386. Abstract 1811.
This study made in Birmingham, AL, US, on pigs (N: 6) showed that randomly timed shocks delivered during ongoing compressions had a similar defibrillation threshold as shocks during a 3-5 s pause. The defibrillation threshold varied with shock timing with respect to the different LUCAS™ 1(V1) compression phases. The authors concluded that shocks can be delivered during ongoing LUCAS compressions without compromising efficacy, removing the need for potentially detrimental pauses in compressions.

Ristagno G, Tang W, Wang H, Sun S, Weil M. Comparison between mechanical active chest compression/decompression and standard mechanical chest compression. *Circulation*. 2007;116:II929-II930. Abstract 31.
This study made at the Weil Institute in California, US, on (39kg) pigs (N: 10) compared LUCAS™ 1(V1) with Thumper (Michigan Instruments, US) after 5 min VF followed by 5 min of CPR. LUCAS created significantly higher blood flow compared to Thumper, a higher negative intrathoracic pressure in the decompression phase, a higher coronary perfusion pressure (31 mmHg vs. 19 mmHg), a higher $EtCO_2$ (28.6 mmHg vs. 22.5 mmHg) as well as an increased carotid artery blood flow (84.3 mL/min vs. 70 mL/min). Thumper caused significantly more broken ribs.

Rubertsson S, Karlsten R. Increased cortical cerebral blood flow with LUCAS, a new device for mechanical chest compressions compared to standard external compressions during experimental cardiopulmonary resuscitation. *Resuscitation*. 2005;65:357-363.
In this study made in Uppsala, Sweden, LUCAS™ 1(V1) was evaluated against a standardised "manual" CPR device in pigs (N: 14) with the aim to measure and compare the cerebral flow. The standardised "manual" CPR device was set regarding depth (5cm) and frequency (100) similarly to LUCAS, but had no suction cup (i.e. no assisted recoil) and a less controlled duty-cycle. LUCAS created a significantly higher cortical cerebral flow (65% of the baseline/normal value) vs. the standard manual CPR (40% of the baseline/normal value). Flow of over 50% of baseline/normal flow could result in return of consciousness and awareness during CPR. End-tidal CO2 values were significantly higher during LUCAS compressions. End-tidal CO2 values are known to correlate well to cardiac output during CPR.

Steen S, Liao Q, Pierre L, Paskevicius A, Sjöberg T. Continuous intratracheal insufflation of oxygen improves the efficacy of mechanical chest compression-active decompression CPR. *Resuscitation*. 2004;62:219-227.
This study made in Lund, Sweden, in pigs (N: 16) compared two different ventilation methods during LUCAS™ 1(V1) CPR; continuous insufflation of oxygen (CIO) and intermittent positive pressure ventilation (IPPV). LUCAS CPR combined with CIO resulted in an adequate ventilation, significantly better oxygenation and a higher coronary perfusion pressure (around 25mm Hg) compared to the IPPV group (around 15 in CPP).

Steen S, Liao Q, Pierre L, Paskevicius A, Sjöberg T. The critical importance of minimal delay between chest compressions and subsequent defibrillations: a haemodynamic explanation. *Resuscitation*. 2003;58:249-258.
This study made in Lund, Sweden, examined the pathophysiology of fibrillating heart in pigs (N: 18). During the first 3 min of ventricular fibrillation (VF) the arterial blood was transported to the venous circulation, with the consequence that the left ventricle emptied and the right ventricle became greatly distended. After about 5 minutes, the blood pressures on the arterial and venous side reached equilibrium, resulting in zero coronary perfusion pressure and no carotid flow. It took 10 s of LUCAS™1(V1) compressions to regain acceptable flow in the carotid artery, however, it took one minute to bring back a negative CPP to zero, and a further half minute to bring it up to adequate levels (greater than or equal to15 mmHg). Adequate heart massage before and during defibrillation greatly improved the likelihood of return of spontaneous circulation.

Steen S, Liao Q, Pierre L, Paskevicius A, Sjöberg T. Evaluation of LUCAS, a new device for automatic mechanical chest compression and active decompression for cardiopulmonary resuscitation. *Resuscitation*. 2002;55:289-299.
This Swedish first publication on LUCAS™ 1(V1) evaluated LUCAS CPR vs. manual CPR in four different pig models (total N:100). LUCAS provided significantly better circulation to the brain and heart and more ROSC compared to manual CPR; increased coronary perfusion pressure (CPP; 17 mmHg vs. 10 mmHg), higher cardiac output (0.9 l/min vs. 0.5 l/min) higher carotid artery blood flow (58 ml/min vs. 32 ml/min) and more ROSC (83% vs. 0%). LUCAS square-shaped compressions created a higher pressure and flow than the peak-shaped manual ones in an artificial thorax model. The publication contains a pilot study of the first 20 human LUCAS cases, highlighting a life-saving case. The authors concluded that LUCAS was easy to use and apply and appreciated by staff for freeing resources and facilitating rescue. The device fit on stretchers, worked well within ambulances, and defibrillation was possible during ongoing compressions.

MANIKIN STUDIES

Lindblad P, Åström Victorén A, Axelsson C, Madsen Hardig B. Comparing manual and mechanical chest compression quality parameters in 30:2 mode with the use of a novel approach. *Circulation*. 2011;124:A230. Abstract. (Poster on file at Physio-Control.)
This is a Swedish study comparing the quality of chest compressions between manual and LUCAS™2 CPR in different scenarios, using a modified manikin that could record impedance signals that were summarized by the Code Stat program. The LUCAS back plate was applied with 5 second interruption to chest compressions, and the Upper Part with 11-18 sec. During a 10 minute 30:2 CPR scenario, the interruptions were fewer and shorter with LUCAS CPR vs. manual CPR (100 sec vs. 129 sec) (p=0.001) and the chest compression ratio was higher with LUCAS (84% vs. 79%, p=0.0003). The difference in results was due to a higher frequency in manual CPR group vs. LUCAS group (116 vs. 99) causing more ventilation pauses (30:2) per minute, together with longer ventilation pauses in the manual group as well as more interruptions due to rotation of rescuers every 2 minutes. When the scenario included movement and transportation of the manikin, the difference in quality and interruption time between the two methods was even more pronounced.

Blomberg H, Gedeborg R, Berglund L, Karlsten R, Johansson J. Poor chest compression quality with mechanical compressions in simulated cardiopulmonary resuscitation: A randomized, cross-over manikin study. *Resuscitation*. 2011;82:1332-1337.
This is a Swedish study measuring the time to first defibrillation and the no flow time prior to the first defibrillation comparing manual chest compressions with LUCAS™ 2 chest compressions in a manikin set up. 21 pre-hospital teams, consisting of 2 rescuers in each, and who had used LUCAS in their routine practice, were randomized to two identical 10 minute long CPR scenarios with or without the aid of LUCAS. The study showed there were no differences between LUCAS vs. manual CPR in time to first defibrillation (182 s vs. 178 s, p=0.56) or hands-off time before the first defibrillation (79 s vs. 73 s, p=0.04) – showing that LUCAS could be applied quickly without causing detrimental interruptions to chest compressions. There was also no difference in the hands-off fraction during the whole scenario (30% vs. 33%). The authors noted, however, that only 58% of the LUCAS compressions were meeting guidelines depth (defined as >38mm according to G2005) whereas the manual CPR met guidelines depth in 88% of the compressions. The LUCAS compressions were found shallow (median 3.8 cm) compared to manual compressions (median 4.7 cm). The authors suggest the poor depth results from LUCAS were due to the users' failure to recognize and correct a malposition of the device and that this might counteract a potential benefit of mechanical chest compressions. Response by Physio-Control/Jolife AB (Nilsson A, Chapman FW, Resuscitation 2012 Jan 29 epub ahead of print) emphasized that the depth measurements by the manikin used in this study were flawed, and that the depth measurement error was more pronounced in the LUCAS group due to the curved LUCAS back plate causing a gap to the manikin's flat back and making the manikin flex downwards during each LUCAS compression.

Münch M, Rehatscheck G, Strohm M, Schenk I, Hering R. Resuscitation in Rescue Helicopter (RTH) – the feasibility and efficacy of a mechanical CPR device in an RTH simulator. (Translated from German language.) *Intenziv und Notfallmedizin*. 2010:4;295.
This is a German study on the quality of manual vs. mechanical CPR during a simulated 20 minutes long flight in a rescue helicopter with a resuscitation event. 13 teams with 2 people in each were randomized to a defined 14 min long resuscitation scenario with or without the LUCAS™ 2 device. The compression pauses was less with LUCAS (120+60 sec) compared to manual (176+80 sec). The authors conclude that the use of the LUCAS 2 device was possible in an EC 135 helicopter and its use resulted in guidelines compliant compressions measured as depth, frequency, pauses, share of effective compressions, compared to conventional manual chest compressions.

Wyss C, Fox J, Franzeck F, et al. Mechanical versus manual chest compression during CPR in a cardiac catherisation settting. *Cardiovascular Medicine*. 2010;13:92-96. (http://www.cardiovascular-medicine.ch/pdf/2010/2010-03/2010-03-005.PDF)
This is a Swiss study on the quality of ten minutes of chest compressions provided manually by a three experienced resuscitators (rotating every minute) compared to when provided by LUCAS™1(V2) and by LUCAS™2. The test was done on a manikin in a cath lab set up. The quality was significantly higher with the two LUCAS devices compared to manual CPR. 98% of the LUCAS compressions had a correct depth versus 70% of the manual compressions (p<0.01). Of the manual compressions 8% were too deep and 21% too shallow. The hands-off time due to application of the LUCAS device was on average 10 seconds (9-11 seconds) whereas the hands-off time due to change of rescuers was on average 9 seconds (8-12 seconds). The frequency was similar in all groups but showed lower variation with LUCAS (99-102/min) vs. manual CPR (88-121/min).

Glasheen J, Hennelly D, O'Donnell C. Effectiveness of single rescuer delivered chest compressions using 15:2 versus 30:2 in both static and mobile environments compared with an active decompression device. *Prehosp Emerg Care*. 2007;11:95.
This manikin test compared LUCAS™ 1(V1) with manual CPR (30:2 ratio) performed by a group of 20 paramedics in Ireland. On a manikin on the floor, LUCAS delivered effective compressions 99.2% of the time whereas manual delivered effective CPR 70.9% of the time. On a stretcher in a moving ambulance, LUCAS delivered effective compressions during 99.2% vs. 51.7% of the time in the manual group.

REVIEW AND MISCELLANEOUS ARTICLES

Ferrari M, Lauten A, Figulla H. Kardiokompressionssysteme zur Reanimation im akuten Kreislaufstillstand (Cardiocompression systems for resuscitation in acute cardiac arrest). [article in German and abstract in English]. *Notfall Rettungsmed*. 2011;14:618-623.
This is a German language review article on mechanical CPR; the latest guidelines, benefits of continuous and effective mechanical CPR, safety and efficacy aspects during transportation and during PCI in cath lab.

Olivecrona G, Noc M. Percutaneous Coronary Intervention during cardiac arrest and ongoing chest compressions. *Interven Cardiol*. 2011;6:12–16.
This is a review article on the use of mechanical CPR devices during cath lab interventions and discusses how mechanical CPR can maintain circulation during prolonged cardiac arrest in the cath lab, may be superior to the use of manual chest compressions, and how mechanical chest compressions facilitate potentially lifesaving continued coronary intervention or can be used as a bridge to ECMO or other means of cardiopulmonary bypass.

Brodmann Maeder M, Dünser M, Balthasar E, et al. The Bernese Hypothermia Algorithm: A consensus paper on in-hospital decision-making and treatment of patients in hypothermic cardiac arrest at an alpine level 1 trauma centre. *Injury*. 2011;42:539-43.
This is a paper from Bern, Switzerland describing their algorithm for in-hospital treatment of pre-hospital patients with hypothermic cardiac arrest (typically avalanche victims), with a primary focus on the decision making process for the administration of ECC (extracorporeal circulation). LUCAS is part of the algorithm to provide chest compressions while an interdisciplinary team decides whether to take the patient to the operating room to perform a number of diagnostic interventions before deciding on rewarming with ECC or not. The article is interesting as it provides a good overview of all considerations and decision makings that need to be taken during ongoing CPR, where LUCAS is an integral part of the algorithm.

Sunde K. All you need is flow. *Resuscitation*. 2010;81:371–372.
An editorial that refers to Wagner et al, 2010 and Larsen et al, 2010, which are published in the same issue, and it highlights the opportunities for increased survival with LUCAS.

"While the study from Larsen et al. demonstrates that a sufficient coronary perfusion pressure and flow is achievable with this method, the study from Wagner et al., which is the far biggest case series so far, demonstrates the survival benefit. […] With continuous mechanical chest compressions while preparing for and performance of coronary angiography/PCI, it is possible to save lives of patients that would otherwise die. This approach has several aspects that will impact on cardiac arrested patients' possibility for survival. First, with uninterrupted mechanical chest compressions of good quality, vital circulation is maintained. You "buy time" in calm and quiet conditions while focusing on lifesaving invasive procedures. Secondly, the coronary angiogram will diagnose the cause of the arrest and can immediately be followed with a definitive PCI, if indicated. Thereafter, defibrillation can follow, and sustained ROSC is easier to achieve. Moreover, if PCI is not possible, but serious coronary disease has been discovered that requires immediate cardiac surgery, the mechanical chest compression device can be used as "a bridge" before bypass is achieved with a heart lung machine.

Jacobs I. Mechanical chest compression devices - Will we ever get the evidence? *Resuscitation*. 2009;80:1093–1094.
A letter to the editor that discusses the difficulties to do high-quality, randomized studies in sudden cardiac arrest patients.

Sunde K. Experimental and clinical use of ongoing mechanical cardiopulmonary resuscitation during angiography and percutaneous coronary intervention. *Crit Care Med.* 2008;36(Suppl.): S405–S408.
This review article aimed to document if angiography and PCI is feasible during ongoing mechanical chest compressions, and summarizes LUCAS publications from this area. It concludes that angiography and PCI is feasible and an alternative approach to achieve return of spontaneous circulation in cardiac arrest patients with suspected myocardial infarction.

Noc M, Radsel P. Urgent invasive coronary strategy in patients with sudden cardiac arrest. *Curr Opin Crit Care*. 2008;14:287–291.
This is a review of the evidence on urgent coronary angiography and PCI after resuscitated cardiac arrest and during ongoing resuscitation. Urgent PCI should be attempted in conscious patients after ROSC similarly as in patients with acute myocardial infarction without preceding cardiac arrest. In comatose survivors, urgent angiography is reasonable if infarction is suspected and if there is realistic hope for neurological recovery that should be facilitated with mild induced hypothermia. Urgent angiography and PCI may be successful also during ongoing resuscitation in selected patients without advanced heart diseases and significant comorbidities.

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