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Clinical paper

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☆

David Smekal[a,*], Jakob Johansson[a,b], Tibor Huzevka[a], Sten Rubertsson[a]

[a] Department of Surgical Sciences - Anaesthesiology & Intensive Care, Uppsala University, SE-751 85 Uppsala, Sweden
[b] Centre of Emergency Medicine, Uppsala University Hospital, SE-751 85 Uppsala, Sweden

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ABSTRACT

Aim: To compare the variety and incidence of internal injuries after manual and mechanical chest compressions during CPR.
Methods: In a prospective pilot study conducted in two Swedish cities, 85 patients underwent autopsy after unsuccessful resuscitation attempts with manual or mechanical chest compressions, the latter with the LUCAS™ device. Autopsy was performed and the results were evaluated according to a specified protocol.
Results: No injuries were found in 26/47 patients in the manual group and in 16/38 patients in the LUCAS group ($p = 0.28$). Sternal fracture was present in 10/47 in the manual group and 11/38 in the LUCAS group ($p = 0.46$), and there were multiple rib fractures (≥3 fractures) in 13/47 in the manual group and in 17/38 in the LUCAS group ($p = 0.12$). Bleeding in the ventral mediastinum was noted in 2/47 and 3/38 in the manual and LUCAS groups respectively ($p = 0.65$), retrosternal bleeding in 1/47 and 3/38 ($p = 0.32$), epicardial bleeding in 1/47 and 4/38 ($p = 0.17$), and haemopericardium in 4/47 and 3/38 ($p = 1.0$) respectively. One patient in the LUCAS group had a small rift in the liver and one patient in the manual group had a rift in the spleen. These injuries were not considered to have contributed to the patient's death.
Conclusion: Mechanical chest compressions with the LUCAS™ device appear to be associated with the same variety and incidence of injuries as manual chest compressions.

1. Introduction

In 2005, the European Resuscitation Council (ERC) and the American Heart Association revised the guidelines for resuscitation, which resulted in increased focus on the importance of chest compressions.[1] A new algorithm was constructed to reduce the hands-off interval and possibly improve the quality of cardiopulmonary resuscitation (CPR). During resuscitation, chest compressions are only performed for about 50% of the time and the majority of the compressions are too shallow.[2] In addition, at best manual chest compressions only achieve a cardiac output of approximately 20–30% of the normal,[3–5] and owing to fatigue the quality of the compressions decreases after a few minutes.[6] Also, it is difficult to perform high quality CPR during transport.[7] This supports the need for a mechanical device that will improve the delivery of chest compressions. In 1908, a mechanical device was developed to deliver external chest compressions,[8] and up until the 1990s several different devices were produced, but with poor results.[9,10] In 2002, a new device called LUCAS™ was marketed, and this appears to have improved vital organ blood flow in experimental studies.[11,12]

Internal injuries after manual and mechanical chest compressions are common and the most frequently reported complications of CPR are skeletal injuries, especially to ribs and the sternum.[13] Furthermore, complications from the upper airway, lungs, heart, and great vessels, and injuries to the gastrointestinal system, including laceration of the liver or spleen and retroperitoneal haemorrhage, have been reported to occur with varying frequencies.[13–28] Recently there have been discussions regarding a postulated increase in the frequency and severity of internal injuries after mechanical chest compressions during CPR. However, these discussions have often been based upon case reports or undersized studies.[30] Only a few studies highlight the adverse effects of both manual and mechanical CPR.[22,31,32]

The aim of this study was to compare the variety and incidence of internal injuries, as assessed by autopsy, after manual and mechanical chest compressions during CPR. It was hypothesised that there is no difference in the incidence of injuries after manual chest com-

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* Corresponding author. Tel.: +46 18 6110000; fax: +46 18 559357.
E-mail address: david.smekal@akademiska.se (D. Smekal).

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pressions during CPR compared with that after mechanical chest compressions with the LUCAS™ device.

2. Materials and methods

2.1. Study population and design

The study was reviewed and approved by the human ethics committee in Uppsala, Sweden. This committee waived the need for informed consent. In this prospective pilot study, conducted from February 1st 2005 to April 1st 2007, patients not surviving cardiac arrest at Uppsala University Hospital and Gävle County Hospital, Sweden, underwent autopsy based upon a decision taken by the admitting physician. Swedish law regulates the possibility of autopsy, and briefly, the relatives' view determines whether there will be an autopsy unless a forensic autopsy is required.

The patients had been treated with either manual (manual group) or mechanical chest compressions, the latter with the LUCAS™ device (LUCAS group), according to ERC guidelines regarding advanced cardiac life support.[33] During the study period, an efficacy study was being carried out to compare the LUCAS™ device with manual chest compressions in out-of-hospital cardiac arrest, and 84% of the present study population was also included in the efficacy study. The LUCAS™ device had not been used in the ambulance services in the cities of Uppsala and Gävle prior to the start of the present study. Therefore, all Emergency Medical Service (EMS) personnel received one day of manikin hands-on training and theoretical education during the end of 2004. Just before the study begun, they received a new training session with repetition of the practical and theoretical items. During the study there was an ongoing process of repetition and evaluation of the use of the LUCAS™ device. The emergency system in the two cities included were first-tier systems with ambulance crews consisting of at least one registered nurse. All first-tier ambulances were equipped with the LUCAS™ device. In both cities, one central dispatching centre simultaneously alerted two emergency ambulances. The inclusion criterion was sudden cardiac arrest, and the exclusion criteria were known pregnancy, age under 18 and trauma. Closed letter randomisation was performed by one of the EMS personnel after the detection of the cardiac arrest. If randomised to the LUCAS group, the patients were treated with manual chest compressions while the LUCAS™ device was being unpacked and applied.

The remaining 16% of the patients included were in-hospital patients who had undergone unsuccessful resuscitation attempts with manual chest compressions ($n = 11$) or mechanical compressions with the LUCAS™ device ($n = 3$) by intensive care doctors on arrival of the latter at the scene. During the study period, only a fraction of the intensive care doctors had received proper training with the LUCAS™ device and thus it was not possible to randomise cardiac arrest victims in hospital. Owing to lack of data, information on CPR times was not available for the patients with in-hospital cardiac arrest.

Pathologists in each of the two centres recorded data from the autopsy through a standardised study protocol for external and internal injuries. It was not possible to blind the pathologists to the treatment given because of patient charts and due to marks from the suction cup on patient's chest. This protocol, which was similar to that used by Englund and Kongstad,[30] included recording of skin marks, sternal fractures, rib fractures, bleeding in the mediastinum, injuries to the heart, injuries to the thoracic aorta, haemothorax, pneumothorax and injuries to the liver and/or spleen.

2.2. The properties of LUCAS™

The LUCAS™ device is gas-driven, and provides automatic mechanical compression and active decompression back to the neutral position of the chest. It consists of a silicon rubber suction cup similar to that used in the CardioPump®, and a pneumatic cylinder mounted on two legs and connected to a stiff back plate. At the time of the study, the system was powered by air from a cylinder, the gas system in ambulances, or the gas outlets in hospitals. The maximum compression force is 550 N and the maximum compression depth is 4–5 cm. The default setting is fixed for compression/decompression at a frequency of 100 per minute. The height of the suction cup can be adjusted to fit patients with an anteroposterior thorax diameter in the range of 175–265 mm. In May 2006, the LUCAS™ device was modified with a stabilisation strap to prevent it from sliding in the caudal direction. LUCAS™ is CE marked and is marketed both in Europe and in the USA.

Table 1
Demographic data of patients included.

	LUCAS (38)	Manual (47)	p value
Age (years)	72 ± 12	66 ± 17	0.38
Sex (male)	27	31	0.65
CPR time (min)	42 ± 19	36 ± 13	0.11

Mean ± S.D. or numbers of patients.

2.3. Statistical analysis

The statistical analyses were performed by independent statisticians at the Uppsala Clinical Research Centre, Uppsala, Sweden. Data were analysed with SAS version 9.1 (SAS Institute, Cary, NC, USA). The groups were tested for the dichotomous variables with Fisher's exact test and for continuous variables with the Mann–Whitney U-test. Values are reported as mean ± standard deviation. A p value of <0.05 was considered significant.

3. Results

Of the 85 patients included, 47 (55%) received manual CPR and 38 (45%) were treated with the LUCAS™ device. There was no difference in age, sex or duration of CPR by EMS personnel between the two groups and there was no correlation between these parameters and the incidence of rib and sternal fractures. Demographic data of the patients included are presented in Table 1.

In the LUCAS group, the average duration of initial manual compression was 2.9 ± 2.1 min before the LUCAS™ device was started. Bystander CPR was performed on 13 patients in the LUCAS group and on 25 patients in the manual group ($p = 0.12$). Eleven patients in the manual group and three patients in the LUCAS group were recruited from patients with in-hospital cardiac arrest.

No injuries were found in 26/47 patients in the manual group and in 16/38 patients in the LUCAS group ($p = 0.28$). The frequency of injuries is summarised in Table 2. Fracture of the sternum was present in 10/47 in the manual group and 11/38 in the LUCAS group ($p = 0.46$), and multiple rib fractures (≥3 fractures) were present in 13/47 in the manual group and 17/38 in the LUCAS group ($p = 0.12$). Bleeding in the ventral mediastinum was noted in 2/47 (manual) and 3/38 (LUCAS, $p = 0.65$), retrosternal bleeding in 1/47 (manual) and 3/38 (LUCAS, $p = 0.32$), epicardial bleeding in 1/47 (manual) and 4/38 (LUCAS, $p = 0.17$), and haemopericardium in 4/47 (manual) and 3/38 (LUCAS, $p = 1.0$). There was one ruptured abdominal aortic aneurysm in the LUCAS group and one thoracic aortic dissection in both groups, all of which were considered by the pathologist to be the primary cause of cardiac arrest and not injuries from treatment.

One patient in the LUCAS group had a 4 cm rift in the liver and one patient in the manual group had a rift in the spleen with bleeding. These injuries were not considered to have contributed to the patient's death. Pneumothorax was observed in one patient in each group. One patient in the LUCAS group had bleeding in the lung