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Clinical paper

Assessment of CPR interruptions from transthoracic impedance during use of the LUCAS™ mechanical chest compression system☆

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ABSTRACT

Background: Quality of cardiopulmonary resuscitation (CPR) is a key determinant of outcome following out-of-hospital cardiac arrest (OHCA). Recent evidence shows manual chest compressions are typically too shallow, interruptions are frequent and prolonged, and incomplete release between compressions is common. Mechanical chest compression systems have been developed as adjuncts for CPR but interruption of CPR during their use is not well documented.
Aim: Analyze interruptions of CPR during application and use of the LUCAS™ chest compression system.
Methods: 54 LUCAS 1 devices operated on compressed air, deployed in 3 major US emergency medical services systems, were used to treat patients with OHCA. Electrocardiogram and transthoracic impedance data from defibrillator/monitors were analyzed to evaluate timing of CPR. Separately, providers estimated their CPR interruption time during application of LUCAS, for comparison to measured application time.
Results: In the 32 cases analyzed, compressions were paused a median of 32.5 s (IQR 25–61) to apply LUCAS. Providers' estimates correlated poorly with measured pause length; pauses were often more than twice as long as estimated. The average device compression rate was 104/min (SD 4) and the average compression fraction (percent of time compressions were occurring) during mechanical CPR was 0.88 (SD 0.09).
Conclusions: Interruptions in chest compressions to apply LUCAS can be <20 s but are often much longer, and users do not perceive pause time accurately. Therefore, we recommend better training on application technique, and implementation of systems using impedance data to give users objective feedback on their mechanical chest compression device use.

1. Introduction

Each year, about 55 people per 100,000 suffer from sudden cardiac arrest (SCA) and are treated by EMS; fewer than 10 percent survive.[1] One key determinant for the likelihood of successful resuscitation is the quality of the cardiopulmonary resuscitation (CPR) administered. Chest compressions must be delivered at the proper rate, depth, and duty cycle, the chest must be allowed to recoil fully between compressions, and pauses in compressions must be kept to an absolute minimum.[2] Compressions provided by trained rescuers often fail to meet nationally recognized guidelines.[3]

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Human performance factors are the major causes of poor CPR quality. Products that measure CPR parameters can now give real-time feedback to providers but have yielded only modest improvements in CPR quality.[4] The influence of human factors can be further reduced by using mechanical chest compression systems.[5–8] While such devices have been available for decades, only recent products designed for ease of use and increased reliability have gained popularity.

The LUCAS chest compression system (Jolife AB, Sweden) is used in many European communities and American emergency medical services (EMS) agencies. Experimental evidence has shown that mechanical compressions are associated with increased coronary perfusion pressure and blood flow relative to manual compressions.[9] Mechanical systems such as LUCAS provide trapezoidal compression waveforms, recently shown to be associated with higher mean aortic and coronary perfusion pressures than sinusoidal compression waveforms like those of manual compressions.[10] Furthermore, chest compression devices may make it possible to provide more continuous compressions by shortening some pauses in compressions and eliminating the need for other pauses.

While compression devices can deliver excellent compressions, it takes time to put the device on the patient and for some of that time compressions must be paused. A recent evaluation of CPR interruptions during use of another chest compression device has raised particular concern about the interruption time for device application.[11] If this application pause is too long, it is possible that its deleterious effects could outweigh the benefits of mechanical compressions. Therefore, the length of time that chest compressions are interrupted while the device is applied to the patient may be an important figure of merit to measure for mechanical chest compression systems.

The aim of this study was to analyze the interruption of CPR during application and use of the LUCAS™ chest compression system. We gathered rescuer perceptions of pause length during application of LUCAS and compared these perceptions to actual measures of pause length obtained by analyzing transthoracic impedance data gathered by defibrillators. In addition we measured interruptions in CPR during pre and post shock delivery and calculated overall compression fraction times for each cardiac arrest.

2. Methods

The North American LUCAS Evaluation (NALE) project, described elsewhere, included deployment of LUCAS devices in four US EMS agencies and evaluation of their usability.[12] From November 2008 to February 2010, the NALE project collected surveys from responders after they used a LUCAS device to treat 327 patients with out-of-hospital cardiac arrest (OHCA). This study focused on a subset of those patients from three of the EMS agencies (Table 1), combining one element of the NALE usability data with additional physiological data. Cases from the fourth agency were not included because that agency did not use defibrillators that collected the impedance data required for CPR measurements.

Table 1
Participating agencies and device distribution.

Agency	Location	Number of devices
Allina Medical Transportation	Anoka County, Minnesota	36
Anchorage Fire Department	Anchorage, Alaska	6
Contra Costa County EMS	Contra Costa County, California	12

The chest compression device used (LUCAS 1 operated on compressed air, Jolife AB) is cleared for marketing by the US Food and Drug Administration and is used as a tool for CPR globally. All data received were de-identified, and no protected health information was included in the data. Each agency obtained study approval from either their quality assurance office or a local institutional review board according to local protocol. In all cases, the patient was at least 18 years of age and not known to be pregnant. Presumed traumatic arrests were excluded. SCA was defined as unconscious and without a pulse upon arrival at patient's side. All arrest rhythms were included.

To measure the perceived length of time compressions were stopped to apply the chest compression device, prehospital providers were asked to complete a simple survey after each case that included a question on that topic (Table 2).

Electrocardiogram and impedance data downloaded from the defibrillator/monitors (LIFEPAK® 12 Monitor/Defibrillators, Physio Control, Inc., Redmond, WA) were retrospectively collected. These devices continuously deliver a high frequency, low amplitude carrier signal between the defibrillation electrodes, which is used to determine transthoracic impedance, a signal that shows the timing of chest compressions and pauses.[13] CPR analytics software (CODE-STAT 8.0 Data Review Software, Physio-Control, Inc., Redmond, WA) was used to process the defibrillator data. The software automatically annotates chest compressions; for each case, an oversight committee of two experts (DY/RP) manually verified those annotations and corrected any inaccuracies. Five performance features were calculated based on the corrected annotations: (1) the length of the CPR interruption due to application, (2) the length of pre-shock CPR interruptions, (3) the length of post-shock CPR interruptions, (4) the compressions fraction for mechanical CPR, and (5) the compressions rate for mechanical CPR. These features are important clinical indicators of the usability and performance of the device.[11,14]

2.1. CPR interruption due to mechanical device application

The manufacturer recommends application of the LUCAS device in two steps: (1) place the back plate under the patient and continue compressions and (2) after a cycle of compressions, connect the top portion of the device to the back plate, adjust the vertical position of the suction cup and pressure pad and begin mechanical CPR. The length of the main pause for application, step 2 above, was clearly identified and measured using the impedance signal; mechanical compressions are distinguished from manual compressions by their highly regular, rectangular morphology (Fig. 1). We defined the CPR interruption interval as the time from the trailing edge of the last manual compression to the leading edge of the first mechanical compression. Usable data files included impedance data for the entire transition from manual to mechanical CPR and had low artifact. Data files lacking thoracic impedance

Table 2
Survey question about estimated length of pause in chest compressions, with responses.

Question/answers	Number of responses	%
Approximately how long was CPR stopped to apply the top portion of the compressor to the backboard before resuming CPR?	113	100%
<10 s	25	22.1%
10–20 s	56	49.6%
20–30 s	26	23.0%
>30 s	2	1.8%
No answer	4	3.5%