Resuscitation 80 (2009) 1099–1103

Contents lists available at ScienceDirect

Resuscitation

journal homepage: www.elsevier.com/locate/resuscitation

Clinical paper

Mechanical active compression–decompression cardiopulmonary resuscitation (ACD-CPR) versus manual CPR according to pressure of end tidal carbon dioxide ($P_{ET}CO_2$) during CPR in out-of-hospital cardiac arrest (OHCA)☆

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ARTICLE INFO

Article history:
Received 17 April 2009
Received in revised form 10 July 2009
Accepted 6 August 2009

Keywords:
Out-of-hospital cardiac arrest
Mechanical compression
End tidal carbon dioxide

ABSTRACT

Aim: In animal and human studies, measuring the pressure of end tidal carbon dioxide ($P_{ET}CO_2$) has been shown to be a practical non-invasive method that correlates well with the pulmonary blood flow and cardiac output (CO) generated during cardiopulmonary resuscitation (CPR). This study aims to compare mechanical active compression–decompression (ACD) CPR with standard CPR according to $P_{ET}CO_2$ among patients with out-of-hospital cardiac arrest (OHCA), during CPR and with standardised ventilation.
Methods: This prospective, on a cluster level, pseudo-randomised pilot trial took place in the Municipality of Göteborg. During a 2-year period, all patients aged >18 years suffering an out-of-hospital cardiac arrest (OHCA) of presumed cardiac etiology were enrolled. The present analysis included only tracheally intubated patients in whom $P_{ET}CO_2$ was measured for 15 min or until the detection of a pulse-giving rhythm.
Results: In all, 126 patients participated in the evaluation, 64 patients in the mechanical chest compression group and 62 patients in the control group. The group receiving mechanical ACD-CPR obtained the significantly highest $P_{ET}CO_2$ values according to the average ($p = 0.04$), initial ($p = 0.01$) and minimum ($p = 0.01$) values. We found no significant difference according to the maximum value between groups.
Conclusion: In this hypothesis generating study mechanical ACD-CPR compared with manual CPR generated the highest initial, minimum and average value of $P_{ET}CO_2$. Whether these data can be repeated and furthermore be associated with an improved outcome after OHCA need to be confirmed in a large prospective randomised trial.

1. Introduction

Success in the resuscitation of patients with out-of-hospital cardiac arrest (OHCA) is dependent on several factors, such as the patient's general condition, the character and severity of the insult, the time interval from cardiac arrest (CA) to the start of bystander cardiopulmonary resuscitation (B-CPR), the quality of B-CPR and the subsequent quality of advanced cardiac life support (ACLS). In patients with OHCA, survival with a good neurological outcome is dependent upon the generation of blood flow to the heart and brain during resuscitation.[1] A coronary perfusion pressure (CPP) of 15 mmHg, at defibrillation, also appears to be necessary for the return of spontaneous circulation (ROSC).[2] Blood flow and CPP during cardiac arrest are related to the quality and continuity of chest compressions during CPR.[3] The direct measurement of blood flow and CPP requires time-consuming invasive methods that are impossible to perform in the pre-hospital setting. Measuring pressure of end tidal carbon dioxide ($P_{ET}CO_2$) has in animal and human studies shown to be a practical non-invasive method to detect pulmonary blood flow, in reality cardiac output (CO), generated during CPR and as an almost immediate indicator for return of spontaneous circulation (ROSC). Previous reports have also presented threshold values under which no resuscitation succeeded.[4–17]

LUCAS™ is a gas-driven device performing mechanical active compression–decompression (ACD) CPR. Active decompression increases the naturally occurring negative intrathoracic pressure by physically expanding the chest wall. During manual CPR, incomplete chest wall recoil is a common error, resulting in significantly less blood flow back to the heart.[18] A randomised animal study showed significantly higher cardiac output, carotid artery blood flow, $P_{ET}CO_2$ levels and CPP with the LUCAS device compared with manual CPR.[19] However, in clinical studies of OHCA, mechanical

☆ A Spanish translated version of the abstract of this article appears as Appendix in the final online version at doi:10.1016/j.resuscitation.2009.08.006.

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doi:10.1016/j.resuscitation.2009.08.006

chest compressions have not yet shown any improvement in survival rates. This study aimed to compare mechanical ACD-CPR with standard CPR according to $P_{ET}CO_2$, among patients with OHCA, during CPR and with standardised ventilation.

2. Methods

2.1. Design

This prospective, on a cluster level, pseudo-randomised pilot study in Göteborg, Sweden, was approved by the local ethical vetting board at Göteborg University, Sweden, on 27 March 2003. During a limited period of about 2 years (22/5/2003 to 25/5/2005), LUCAS™ was exchanged between the three advanced life support (ALS) units for approximate 6-month periods. The cluster method is in reality a non-randomised method but since the CA appears unpredictably and was included by the nearest, available ALS unit, this study can be described as pseudo-randomised.

In the present analysis, only tracheally intubated patients with OHCA of presumed cardiac etiology were enrolled. The exclusion criteria were age <18 years, trauma, pregnancy, hypothermia, intoxication, hanging and drowning, as the judged etiologies behind OHCA, the return of spontaneous circulation (ROSC) before the arrival of the second tier and other reasons, such as terminal illness.

2.2. Organisation

The emergency medical services (EMS) system in Göteborg serves about 450,000 inhabitants in an area of 445 km^2. The ambulances were dispatched according to a two-tier system—i.e. for each call judged to relate to a life-threatening state of health, an ALS unit, if available, and the nearest basic life support (BLS) unit were dispatched simultaneously. The BLS-units were staffed by at least one nurse and the ALS units by a paramedic and a well-trained anaesthesia nurse. In the Göteborg EMS system, three ALS units were available for 24 h every day. All OHCAs were treated according to American Heart Association and European Resuscitation Council guidelines. The criterion for ceasing resuscitation "in the field" is asystole for more than 30 min and this can only be assessed by the nurse in the ALS unit.

2.3. Intervention

Before starting the study, 35 ALS personnel (paramedics and anaesthesia nurses) were trained to perform mechanical ACD-CPR and re-trained in manual chest compression. The instructor was an anaesthesia nurse educated as a LUCAS™ instructor by Jolife AB. Each training session lasted 3 h and ended with a practical and a theoretical test. To pass the test, the participants had to minimise the hands-off time between manual and mechanical chest compressions to less than 20 s. When adapting the training, they were informed about the importance of minimising hands-off situations and preparing for fatigue by rotating the rescuers during manual CPR. In the intervention group, they were told to attach LUCAS to the patient as soon as possible after arriving and before tracheal intubation. In the upstart of the study we randomised, by drawing lots, which two (of three) ALS units to start include patients to the intervention group. The LUCAS device was subsequently exchanged between the three ALS units for approximate 6-month periods during the 2-year study period. Before every half-year period in which the device was used, the EMS personnel took part in a re-training session lasting 2 h.

$P_{ET}CO_2$ was measured during CPR, according to a pre-designed protocol and after the patient was tracheally intubated. Standardised ventilation (7 l/min, 100% O_2) was used and, if $P_{ET}CO_2$ exceeded 6 kPa, the ALS personnel were instructed to increase the ventilation to 8 l/min. $P_{ET}CO_2$ was continuously measured during at least 15 min of CPR or until ROSC was detected. If ROSC was detected, the ALS personal had to note the exact time they detected a pulse-generating rhythm by pressing the "event button" on the Life Pak 12 (LP 12). One milligram of epinephrine was given every second minute up to 5 mg during the measurement period in both groups. The $P_{ET}CO_2$ was measured continuously and automatically recorded twice a minute and for each patient it was categorised as the initial (first obtained value), maximum (highest value), minimum (lowest value) and average value. Since the LUCAS device was applied before intubation, the initial value in the intervention group was recorded during mechanical chest compression.

2.4. Equipment

1. The LUCAS™-device is gas-driven and performs 100 non-interrupted compressions per minute. To run LUCAS, we used compressed air in double tubes that runs LUCAS for approximately 25 min.
2. Ambumatic™ is a volume controlled ventilator with a settable tidal volume from 2 to 12 l/min. The selected tidal volume emanates automatically a breathing frequency.
3. Medtronic "LIFEPAK 12" (LP 12) is equipped with Microstream® Capnography which is a $P_{ET}CO_2$ sensor that continuously monitors CO2. The configuration curve and two values of $P_{ET}CO_2$/min are automatically recorded.

2.5. Unit

In previous reports, $P_{ET}CO_2$ was specified in either mm (millimetre mercury) or kPa (kilo Pascal). This article deals with kPa converted, 1 mmHg = 0.133 kPa.[20]

2.6. Data collection

Data relating to the cardiac arrest cohort were obtained from the Göteborg EMS medical records and computer printouts ($P_{ET}CO_2$). Data were also collected from the dispatch centre and National Registry for Out-of-hospital Cardiac Arrest in Sweden. Further medical data relating to patients admitted alive to hospital were obtained from hospital records. The end-point in the present analysis was $P_{ET}CO_2$, measured after tracheal intubation, during 15 min of CPR or until the detection of ROSC. Additional major clinical study endpoints, analysed for all enrolled patients, were survival to hospital admission and to hospital discharge. Data were collected according to the Utstein criteria.[21]

2.7. Statistical methods

2.7.1. Descriptive statistics

The distribution of variables is given as means, medians or percentages.

2.7.2. Statistical analysis

Comparisons between groups were performed using Fisher's exact test and the Mann–Whitney *U* test for dichotomous and continuous variables, respectively. End tidal carbon dioxide values for each patient were defined as follows: average as mean of all values obtained during the first 15 min, initial value as the first $P_{ET}CO_2$ value obtained, maximum and minimum value as the highest and lowest value, respectively, obtained during the first 15 min. All *p*-values are two tailed and considered significant if below 0.05.