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Clinical paper

Airway pressure and outcome of out-of-hospital cardiac arrest: A prospective observational study☆

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ABSTRACT

Aim: To assess the usefulness of airway pressure as predictor of return of spontaneous circulation (ROSC), as well as to investigate the optimized ventilation compression strategy during cardiopulmonary resuscitation (CPR).

Methods: In this prospective observational study, 300 out-of-hospital cardiac arrest victims were intubated and resuscitated with the use of a ventilator. Mean airway pressure (mPaw) was measured at pre-defined phases of CPR.

Results: A significant difference in mPaw was observed between survivors and non-survivors after the onset of the third minute of CPR. An mPaw value of 42.5 mbar during CPR had specificity and sensitivity of 0.788 and 0.804, respectively, for ROSC (AUC = 0.668, $p = 0.047$). During CPR, we found statistically significant differences in mPaw at phases zero ($F = 4.526$, $p = 0.002$), two ($F = 4.506$, $p = 0.002$), four ($F = 8.187$, $p < 0.0001$), five ($F = 2.871$, $p = 0.024$), and six ($F = 5.364$, $p < 0.0001$).

Conclusion: Mean airway pressure was higher in survivors. A value of 42.5 mbar was associated with ROSC.

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Introduction

After decades of extensive research, the link between the quality of cardiopulmonary resuscitation (CPR) and the generation and maintenance of adequate myocardial blood flow is firmly established. Since the hallmark study of Paradis et al. in 1990,[1] several human and animal investigations have demonstrated a strong association between coronary perfusion pressure (CPP) and return of spontaneous circulation (ROSC).[1–3] However, CPP can only be measured invasively and cannot be used as a routine monitoring variable in the Emergency setting. Currently, the most common way of controlling the resuscitation efforts is monitoring of end-tidal carbon dioxide ($ETCO_2$).[4] In contrast to CPP however, experimental data have established that $ETCO_2$ correlates best with pulmonary blood flow and cardiac output rather than myocardial perfusion.[5,6]

Although the 'thoracic pump' theory is not widely accepted, both 'cardiac pump' and 'thoracic pump' may have a role in forward blood flow during CPR. In fact, chest compression alone may be not sufficient in order for thoracic pump to work and proper timing of compression and ventilation may actually improve the circulation.[7,8] In this context, we have previously theorized that intrathoracic pressure should be evaluated before and after each compression as a non-invasive parameter to reflect the thoracic pump.[9] As changes in intrathoracic pressure may significantly alter airway pressure (Paw), especially during CPR,[10] the aim of this study was to assess the usefulness of Paw as predictor of ROSC, as well as to investigate the optimized ventilation compression strategy during CPR.

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Methods

Study design

This prospective observational study included patients experiencing out-of-hospital cardiac arrest (OHCA). The study complies with the Declaration of Helsinki, while ethical approval for this study was provided by the Hospital's Ethical Committee (No 2855/02-03-2015).[11]

Study setting

The study was undertaken in a large tertiary hospital in Attica, Greece covering an area of 50.4 km^2 with a population of 448,997 residents. In this hospital, OHCA victims are transferred to the Emergency Department (ED) by the National Emergency Medical Service (EMS). The hospital's cardiac arrest team consisted of the on-call anaesthesiologist, the ED's cardiologist, the on-site physician, and the ED's nurses. In case of cardiac arrest, the physician or the nurse calls the members of the cardiac arrest team using predefined numbers and rapidly informs them that there is an arrested patient in the ED, while the on-site physician immediately starts CPR.

For the purposes of the study, the cardiac arrest team consisted of the same ten members (without including the on-site physician) during the study period for five days per week and office hours (Monday–Friday, 8 am–5 pm). This was necessary in order for the members of the team to alternate so as to be five each time. All team members were experienced advanced life support (ALS) providers, while two of them were consultant anaesthesiologists with significant experience in airway management and with a high level of skill and confidence. The ED and the cardiac arrest team were alerted by the EMS crew at least five minutes prior to hospital arrival. After their arrival, all patients were immediately intubated and resuscitated according to the 2010 European Resuscitation Council Guidelines for Resuscitation with the use of a ventilator.[12]

Study devices

In our study, a Draeger Oxylog 2000 portable ventilator (Draeger Medical, Luebeck, Germany), a Datex Ohmeda S/5 Anesthesia Monitor (Datex-Ohmeda Inc, WI, USA), and a CPR metronome were used. These devices were always operated according to the manufacturer guidelines by the same individual, each one for a separate device.

In all resuscitation efforts, ventilatory parameters were intermitted positive pressure ventilation mode, tidal volume 6 ml/kg, respiratory rate 10 min^{-1}, I:E 1:2, PEEP 0 cm H_20, upper alarm limit for maximum Paw during CPR (80 mbar), and FiO_2 100%. The Datex Ohmeda Monitor displays the real time value of mean Paw (mPaw) and is also used for measuring $ETCO_2$ with mainstream method (N-LCM option) using Mainstream CO_2. The CPR metronome was the Omnimedix CPR metronome (http://www.omnimedicsolutions.com/CPRMetronome.html). This metronome is an Android App and can be downloaded and effectively used via an Android smart phone. It plays a sound at 110 beats min^{-1} (to coincide with the currently recommended guidelines for compressions) to give an audible cue to the correct compression rate.

Population

We analyzed the data prospectively collected between March and December 2015 of all OHCA victims aged >18 years who were transported to the ED. Patients were included only if they received at least one minute of CPR by EMS (to increase likelihood of receipt and potential benefit of the study intervention).[13] All victims with obstructed airway and those who could not be intubated after two attempts were excluded from the study. In addition, victims with ROSC prior arrival to ED and those with non-cardiac causes, including pulmonary embolism, stroke, drug overdose, electrocution, and hemorrhage, were also excluded according to the Utstein cardiac arrest criteria for the pre-specified primary study population analyses.[14]

Table 1
Phases of mPaw measurement.

0i	–	End of exsufflation/full chest decompression
0ii	–	End of exsufflation/chest compression[a]
1	–	Middle of insufflation/full chest decompression
2	–	Middle of insufflation/chest compression[a]
3	–	End of insufflation/full chest decompression
4	–	End of insufflation/chest compression[a]
5	–	Middle of exsufflation/full chest decompression
6	–	Middle of exsufflation/chest compression[a]

mPaw—mean airway pressure.
[a] Compression depth 5–6 cm.

Data collection and monitoring

Data analysis was based on predefined data points on a prospective data collection form. The authors as well as all cardiac arrest team members were blinded to measurements until the end of the study and all data were analyzed. Clinical monitoring throughout the study was performed as previously described to maximize protocol adherence.[13] An independent Data and Safety Monitoring research staff monitored safety, ethical, and scientific aspects of the study, while an independent Enrollment research staff was responsible for obtaining prehospital data from the EMS field medical record, as well as for exclusion of all victims not meeting inclusion criteria.

Assessment of mPaw was based on our previous suggestion of increasing intrathoracic pressure in favor of optimizing CPP perfusion pressure. According to our theory, the mechanism of blood flow during CPR is dependent on the stage and momentum of compression or decompression, without forgetting the effect of ventilation as well as that of compression force and rate, which may vary during CPR, especially in relation to time. Therefore, mPaw was measured in pre-defined phases of CPR, as previously suggested (Table 1).[9]

Study endpoints and ethical considerations

The pre-specified primary study endpoint was successful CPR, which was defined as the sustained ROSC for a minimum of 20 min.[14,15] The use of mechanical ventilation did not interfere with resuscitation protocols. Prospective informed consent was not considered practical, and the study was considered to represent no more than minimal risk.[11] The Hospital's Ethical Committee approved the study under a waiver of informed consent.

Statistical analysis

Values are expressed as mean (standard deviation). The normal distribution of each variable was tested by Kolmogorov–Smirnov's test. Continuous variables were expressed as mean ± SD and categorical variables as percentages. Comparisons of continuous variables among the groups were made using analysis of variance (ANOVA) or the Kruskal–Wallis test, as appropriate. Bonferroni adjusted ANOVA, t tests, or Mann–Whitney U tests were used, as appropriate, for pairwise comparisons between the groups. Associations between two categorical variables were tested using x2 tests or Fisher's exact tests. Moreover, models of simple logistic regression were implemented with dependent variable the outcome of

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