Resuscitation 117 (2017) 40–45

Contents lists available at ScienceDirect

Resuscitation

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

Clinical paper

Detection and quantification of gasping during resuscitation for out-of-hospital cardiac arrest☆

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ARTICLE INFO

Article history:
Received 23 February 2017
Received in revised form 30 May 2017
Accepted 31 May 2017

Keywords:
Agonal breathing
CPR
Gasping
Intrathoracic pressure
OHCA
Out-of-hospital cardiac arrest
Return of spontaneous circulation
ROSC

ABSTRACT

Aim: To detect and quantify gasping during cardiopulmonary resuscitation (CPR) in out-of-hospital cardiac arrest (OHCA) patients and to investigate whether gasping is associated with increased return of spontaneous circulation (ROSC).
Materials and methods: A prospective observational study in patients resuscitated and mechanically or manually ventilated for OHCA by emergency physicians of Ghent University Hospital. After intubation, pressure catheters were inserted in the endotracheal tube (ETT) and pressures were measured at the proximal and distal ends of the ETT. Gasping was analysed with custom-developed software and volumes were calculated based on pressure differences between the catheters. Data are expressed as median (interquartile range).
Results: Data were collected in 292 resuscitated patients of whom 36.2% achieved ROSC. Seventy-six of 292 (26.0%) patients showed gasping on the pressure curves during resuscitation. The median gasping volume was 274 ml (196–434). The median gasping rate was 3.7 gasps/min (1.5–7.3). Gasping occurred significantly more in patients displaying ventricular fibrillation as the initial rhythm compared to patients with pulseless electrical activity, pulseless ventricular tachycardia or asystole. The median gasping rate was significantly higher in the ROSC group compared to the non-ROSC group (11.8 gasps/min (95% CI [4.2, 13.9]) and 2.8 gasps/min (95% CI [1.7, 3.9]) respectively ($P < 0.001$)). A gasping rate of >7.3 gasps/min appeared to be the optimal criterion value to herald ROSC. Deeper negative pressures were associated with an increased incidence of ROSC ($P = 0.011$). There was no significant difference in ROSC between patients with gasping and those without.
Conclusion: The occurrence of gasping during CPR was high. Significant gasping volumes were measured. The presence or absence of gasping was not associated with ROSC, but higher gasping rate and deeper negative pressures were.

Introduction

Cardiovascular disease, in particular coronary artery disease, is the leading cause of death in Europe accounting for 4.1 million deaths yearly [1].

In 1973, the *Glossary Committee of the International Union of Physiological Sciences* has defined gasping as an abrupt, sudden and transient inspiratory effort [2]. Gasping is further characterised by short inspiration and expiration and a longer expiratory pause of variable length [3,4]. Gasping typically occurs within the first minute after CA and thereafter follows a crescendo-decrescendo pattern [5–11].

The physiological mechanisms and effects of gasping have been extensively studied in animal models of CA [3]. All these studies emphasize the beneficial effect of gasping during CA on the physiology of the brain, the respiratory system and the circulatory system. A study with pigs showed that gasping results in an immediate decrease of intracranial pressure, causing an increase of cerebral

☆ A Spanish translated version of the abstract of this article appears as Appendix in the final online version at DOI: http://dx.doi.org/10.1016/j.resuscitation.2017.05.031.

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http://dx.doi.org/10.1016/j.resuscitation.2017.05.031
0300-9572/

perfusion, which could be the reason for better neurological outcome in gasping patients [9,10,12]. Another study in pigs showed that gasping can induce a ventilation flow of up to 4 l/min [8], providing higher arterial oxygen tension and lower arterial carbon dioxide tension [5].

In 1991, an analysis was conducted of 445 sound recordings of emergency calls for OHCA. Of all the witnessed CAs, 55% were associated with agonal breathing. In unwitnessed CA, this was 20% [13]. In another study with 113 OHCA patients (witnessed and unwitnessed), gasping was present in 39%. The same study, however, also showed that of all patients who had a CA only after arrival of medical services, 33% showed gasping [14]. In a retrospective analysis of 283 cases of witnessed CA, almost 60% of bystanders described that the patient displayed some kind of breathing. In almost 22% of the cases, bystanders were not able to decide whether the breathing was normal or not. In approximately 40% of the cases, the patient was not breathing at all [15].

Several animal and human studies have shown that gasping increases the likelihood of survival [7,9,10,13,14].

The purpose of the current prospective study was to describe and quantify gasping during cardiopulmonary resuscitation (CPR) in OHCA patients and to determine the occurrence, the rate and the volume of gasping by means of in vivo tracheal pressure waveform analysis. Furthermore, we wanted to investigate the association between the gasping characteristics and the short-term outcome. The potential association between gasping and the initial cardiac rhythm was studied as well.

Based on findings in previous studies and pathophysiological mechanisms, our study hypothesis is that patients who show gasping have a greater chance to achieve return of spontaneous circulation (ROSC). We also hypothesise that patients with a higher gasping rate, greater gasping volumes and deeper negative pressures have a greater chance to achieve ROSC.

Methods

In the city of Ghent and its immediate surroundings (total population 300,000), about 400 CAs are treated yearly by the emergency medical services [16].

The study population of this prospective observational study consisted of adult patients (>18 years) with OHCA who were resuscitated and orotracheally intubated by the physician-staffed Mobile Emergency Team of Ghent University Hospital (serving part of the city) between March 2009 and December 2015.

The Ethics Committee of Ghent University Hospital approved to the study (EC Project Number 2008/025). If the patient achieved ROSC, deferred informed consent to use the data was obtained from the patient or his relatives. If the patient died on the scene or during transport to the hospital, the Ethics Committee waived informed consent.

After orotracheal intubation the intrathoracic pressures were measured. One catheter was attached to the proximal end of the endotracheal tube (ETT) using a connector. The other catheter was inserted into the ETT and positioned approximately 1 cm distally from the tip of the ETT. Two catheters at different depths were needed to measure the pressure differences and hence to calculate gasping volumes. The other endings of the catheters were connected to a custom-made registration device with two pressure sensors (BD Medical, New Jersey, U.S.), two amplifiers (Wheatstone bridge, type 132 B Sensor Amplifier, Datum Electronics, East Cowes, U.K.) and a logger (MSR145, MSR Electronics GmbH, Seuzach, Switzerland) (Fig. 1). For a detailed description of the method and device we refer to our previous work [17]. After orotracheal intubation, the patients were ventilated manually by bag ventilation or mechanically with an Oxylog 3000 ventilator (Dräger, Lübeck, Germany). In the mechanically ventilated patients standard intermittent positive pressure ventilation (IPPV), with or without positive end-expiratory pressure (PEEP) was used at the discretion of the physician of the Mobile Emergency Team. After use, the disposables were checked for the presence of blood or other secretions in the lumen that could have interfered with a correct measurement. Pressure curves were visually checked for quality.

For each included registration, we analysed the episodes during which the patient received botch chest compressions and ventilations. We did not analyse spontaneous breathing after ROSC or after CPR was stopped. ROSC was defined as a sustained perfusing heart rhythm and a palpable pulse. The duration of gasping during CPR was defined as the period from the start of the first gasp until the end of the last gasp.

Software "GVA – Gasp volume analyser"

To analyse the pressure data, a custom program was written in LabVIEW (National Instruments, Austin, Texas, U.S.) and transformed into a user-friendly application. A pressure drop of 5 cm H_2O from the baseline, in which the distally measured pressure had to be more negative than the proximally measured pressure, defined a gasp (Fig. 2). This can be explained by the normal physiology of the respiration: during spontaneous inspiration, the distal intratracheal pressure is more negative than the more proximal pressure. Furthermore, we considered that any respiratory movement of the patient during CPR could occur fragmented if chest compressions are performed simultaneously. The program was developed such that it would recognise those fragments, group them as one gasp and not counting every fragment as a gasp. By doing so, the program enabled detection and quantification of gasping during CPR.

Airflow was calculated from the pressure difference between the catheters and the resistance of the endotracheal tube by means of Rohrer's coefficients of linear and nonlinear resistance [18,19]. Gasping volumes were obtained by integration of airflow over inspiratory time.

Afterwards, all patient data and analyses were imported in SPSS Statistics 23 (IBM, New York, U.S.) for further analysis. To investigate a possible association between gasping and ROSC, a cross tabulation and the Pearson Chi-Square test were performed. For the association between the different gasping characteristics (most negative pressure, gasping rate, gasping volume) and ROSC, the Mann-Whitney U Test was used. For the association between the initial cardiac rhythm and gasping as well as for the gender of the patient and gasping, cross tabulations and the Fisher's Exact Test were performed.

MedCalc (Medcalc Software, Ostend, Belgium) was used for receiver operating characteristics (ROC) curve analysis.

A significance level of $\alpha = 0.05$ was used. Data are expressed as median values (interquartile range).

Results

During the study period, 714 OHCA patients were resuscitated by the Mobile Emergency Team of Ghent University Hospital and registered in our database. Since these pressure measurements were performed only in orotracheally intubated patients, some measurements were started after achieving ROSC. As we intended to measure gasping during the actual CA, 142 patients who were intubated after ROSC were excluded. Furthermore, we found that the registration was not fully reliable in 263 cases, e.g. because of the presence of secretions in the catheters. Eight registrations were performed in patients <18 years and therefore excluded. We had insufficient data for nine patients.