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ORIGINAL RESEARCH

Initial capnography values and resuscitation outcomes of patients assisted by basic life support units in first instance; descriptive prospective study

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Abstract

Introduction: Understanding the key factors which affect out hospital cardiac arrest (OHCA) outcomes is essential in order to promote patient treatment. The main objective of this research was to describe the correlations between the capnographic values obtained during the first minute of monitoring on cardiopulmonary resuscitation, assisted by basic life-support units, with the results as return of spontaneous circulation (ROSC) and alive hospital admission. The secondary objectives were to describe the sociodemographic characteristics of the patients assisted, and to analyze any correlations between receiving basic life-support units and/or defibrillation prior to the arrival of basic life-support units, and the results of the cardiopulmonary resuscitation maneuvers.

Methods: A prospective, descriptive, observational study of adult non-traumatic out hospital cardiac arrest patients was conducted. The patients were initially assisted by basic life-support units on the island of Mallorca, with one minute of initial capnography monitoring.

Results: From July 2018 to March 2020, fifty-nine patients meeting the inclusion criteria were assisted, 76% were men and their mean age was 64.45 ($\pm$15.07) years old. The number of emergency lifesaving technicians who participated in the study was 58, they had a mean work experience of 14.05 ($\pm$6.7) years. Thirty-seven (63.7%) patients underwent basic life-support by bystanders and in 91.5% of cases the semi-automatic external defibrillator was used. Capnometry values during the first minute were obtained in 34 (58.6%) patients, their mean values were 22 ($\pm$19.07) mmHg, 35.5% of patients had values $<$10 mmHg. In 25.4% of the patients, spontaneous circulation returned during cardiopulmonary resuscitation, and 18.6% were admitted to hospital alive.

Conclusion: No correlations were found between initial capnography values scoring above or below 10 mmHg and survival, however, basic life-support maneuvers, and defibrillation by bystanders and first responders, did correlate with survival rates. The average patient assisted in out of hospital cardiac arrest by the basic life-support units sampled was an adult male aged over 65 years.

Keywords

Capnography; Heart arrest; Cardiopulmonary resuscitation

1. Introduction

When facing patients who have arrived in the clinic following an out hospital cardiac arrest (OHCA), initial high quality basic life-support (BLS) measures and early defibrillation, are essential actions to optimise resuscitation results [1]. In patients that receive advanced life-support (ALS) as their initial treatment during OHCA, there are doubts as to whether whis increases survival rates and whether favourable neurological results are obtained [2, 3]. Obviously, early restoration of circulation and therefore oxygenation of critical organs, is a primary objective of cardiopulmonary resuscitation (CPR) [4]. Despite their common occurance, to date, there are still doubts as to which is the best strategy for ventilation and oxygenation [5], especially in situations that are critical for the survival of the patient (including basic or advanced airway management, ventilation rate, tidal volume, etc.) [4].

In the last decade, there has been a significant increase in the use of capnography during CPR [6]. Capnography consists of monitoring levels of carbon dioxide (CO_2) in the exhaled air, commonly referred to as end tidal CO_2 ($EtCO_2$). The first reference to capnography as a valid tool for monitoring the quality of CPR dates back to 1978, in a paper by Dr. Kalenda [7].

Half a century later, capnography has also been validated in its prognostic value for achieving return of spontaneous circulation (ROSC), especially for values >10 mmHg [8]. In fact, recent studies correlate higher initial capnography values in patients that eventually achieve ROSC [9–11]. Capnography has also been shown to be useful in identifying the presence of an early pulse and thus avoiding unnecessary doses of epinephrine [12]. It has been suggested is possible to use capnography during ventilation with a bag valve mask or suplaglottic airway devices (SADs) [13, 14].

It is important to highlight the variability in out-of-hospital emergency medical services (EMS) in different countries. While in places like the US and UK, ALS units are staffed with highly qualified paramedics [15]. In other countries like Spain, there are ALS units operated by medical personnel, and BLS units without medical personnel. The ratio of advanced to basic units varies from region to region. These differences may influence the type and quality of assistance provided to patients in cardiac arrest (CA), especially in more remote areas where BLS units are typically the first to arrive [16].

For these reasons, the main objective of this study was to describe correlations found between the capnometry values obtained in the first minute of capnographic monitoring, from patients assisted initially by BLS units, which achieved recuperation of spontaneous circulation and/or arrived alive at hospital premises. The secondary objectives were to: (a) describe the demographic characteristics of the patients assisted by such units, and (b) to determine whether patients who received basic CPR and/or defibrillation with an automated external defibrillator (AED), prior to the arrival of BLS units, had higher rates of ROSC, and whether they were more likely to be alive when arriving at hospital premises.

2. Methods

An observational, descriptive and prospective study, of patients assisted by BLS units in Mallorca (Balearic Islands, Spain) was conducted. In order to define the target population for the study, data from the SAMU061 Baleares information (IT) systems was analysed and the BLS units that had higher case loads of OHCA assistance prior to the introduction of ALS units in 2017 were identified. Authorization was obtained from the Ethical Research Committee in Balearic Islands (IB 3607/18 PI).

2.1 Study population

Patients were included in the study if they were assisted by any one of the BLS units selected and met the inclusion criteria: aged 18 years old or older, had OHCA not related to trauma, were with one minute of capnography registry.

Exclusion criteria included patients where: initial management was undertaken by medical or health personnel with ALS techniques, OHCA was due to foreign body airway obstruction, ROSC had occurred prior to arrival of the BLS unit, evidence of death was present (rigidity or decomposition), the existence of advanced directives was present, and when people were classified as terminal palliative patients.

The main study variables were: mean capnometry values obtained during the first minute of assistance, achievement of ROSC during CPR, and whether patients were admitted alive into hospital. Secondary variables were: patient sociodemographic variables, the number of years experience the emergency lifesaving technicians (ELT) had, whether basic CPR had been performed by first responders and bystanders, and whether defibrillation had been undertaken prior to the arrival of the BLS unit.

Informed written consent was obtained from either the patients or their next-of-kin, for patients that survived OHCA.

In order to select the study participants, based on a target population of 300 potential candidates, based on previous years data, a probabilistic randomised sample was used, based on inclusion and exclusion criteria.

2.2 Data collection

Data was collected using a data collection sheet and compared with the information registered on the existing IT systems. Capnometry values were obtained with a Philips Heartstart MRx monitor/defibrillator.

2.3 Statistics

Statistical analysis was performed using the IBM SPSS Statistics package v.22 and Microsoft Excel spreadsheets. A Two-tailed contrast test was performed, using a 95% confidence level and an 80% statistical power. When estimating parameters, concrete values and confidence intervals are given. When assumptions were met, parametric analysis was performed, otherwise non-parametric analysis was used.

Standard distribution was estimated using Kolmogorov-Smirnov test, and uniformity of variances was analysed using Levene test.

The presence of non-typical scores was explored, and sensitivity analysis was performed to assess how these scores affected the results.

For the descriptive analysis, quantitative variables were described using mean and standard deviation. Qualitative variables were summarised using frequency tables, which indicated both absolute and relative frequency values; the latter was expressed in percentages.

Bivariate analysis was performed using parametric or non-parametric tests, depending on the situation. For parametric tests, *t*-student, ANOVA and Pearson's correlation were used. The non-parametric tests used were Wilcoxon's or Mann-Whitney U test, Kruskal-Wallis, and Spearman's correlation or chi-squared.

3. Results

The study period started in July 2018 and ended in March 2020. Fifty-nine patients suffering from OHCA were included, their mean age was 64.45 years (±15.07) and 76.3% were men. Table 1 summarises the sociodemographic characteristics of the patients included. With regards to the ELTs, 58 participated in the study, with a mean of 14.05 (±6.7) years of experience.

Out of 59 patients, 37 (63.7%) received basic CPR from bystanders for a mean of 9.84 (±6.41) minutes. The total number of patients that received instrumental BLS from a first

TABLE 1. Demographic characteristics of the patients.

Variable	Sample/Percentage
Coded age	
<65 years	25 (42.4%)
>65 years	34 (57.6%)
Previous illnesses	
Cardiac	10 (17.9%)
Respiratory	3 (5.4%)
Diabetes	4 (7.1%)
Kidney	1 (1.8%)
Smoking	2 (3.6%)
Nothing	15 (26.8%)
Unknown	8 (14.3%)
Other	13 (23.2%)

responder was 39% (n = 23), and AED was used in 91.5% (n = 51) of patients.

Mean capnometry values were recorded during the first minute of CPR monitoring in 34 (58.6%) patients, their mean values were 22 (±19.07) mmHg. In 35.5% (n = 12) of these patients, initial capnometry values were <10 mmHg. The number of complications which were presented during airway management was 23.7% (n = 14), vomiting was the most common complication (16.9%, n = 10). In 50 (86.2%) cases an ALS unit assisted the patient, out of these cases 48 (82.7%) patients received advanced airway management from a physician. ROSC at any point during CPR was achieved in 25.4% (n = 15) of patients, and 18.6% (n = 11) of patients were alive upon hospital admission, the total number of patients who expired after hospital admission was 83.05% (n = 49).

Tables 2,3 show the results obtained after investigating the correlations between the study variables.

4. Discussion

The results obtained show a correlation with latest guidelines [17] and with other recent smaller studies such as the CARO study [18], in that BLS from bystanders and first responders is of paramount importance, in addition to the use of AED devices, for the survival of patients. In our sample, significant correlation was observed between CPR performed by bystanders and use of AED, together with obtaining ROSC (P = 0.000) and being admitted alive into hospital (P = 0.000), as well as the absence of complications in airway management (P = 0.000), and the same results were achieved for CPR.

On the other hand, we did not find statistically significant results with regards to the number of patients that achieved ROSC or were admitted alive into hospital, in relation to the clinical experience of the assisting team of technicians. Capnometry values did not correlate with statistical significance to the clinical experience variable. No correlations were found between capnometry values above or below 10 mmHg, to the critical value of 10 mmHg, and increased ROSC, or with arriving alive to hospital, as has been identified in previous studies [9, 19] and as suggested in the latest CPR guidelines [20], but this focused on patients with orotracheal intubation airway management.

In the literature we only know about the Nakatani *et al*., [21] study, where the results were obtained through the use of a colorimetric $EtCO_2$ detector during CPR were compared. But we could not make a good comparison between the two sets of data as they reported on the medition in a non-especific moment, at minutes 7–15 within the maneuver, and the detectors gave a semiquantitative appraisal, encompassing values between $EtCO_2$ < 0.5% (<3.57 mmHg) and $EtCO_2$ > 2% (>14.28 mmHg). Whereas, they found significant differences in the patients admitted to hospital according to the $EtCO_2$ levels obtained (<0.5% or >2%). Other publications such as Blank *et al*., [22] studied the utility of the colorimetric $EtCO_2$ detector, in order to make early detections of heart rate increases in the delivery room; that work suggested that capnography can be used to detect ROSC during BLS applied by healthcare teams, but this was not an objective of our study.

Presently, we continue to find controversial results with regards to superiority, and better CPR results in patients with OHCA assisted initially by ALS units, while other studies show better survival rates in patients that receive ALS early on [3, 23]. Another study showed a tendency in obtaining poorer neurological outcomes in patients assisted by ALS units initially [2].

The limitations of this study are those associated to the small sample size, as well as the fact that it focuses on CPA cases that were assisted initially by a BLS unit, however data for patients assisted initially by an ALS unit, during the same time period was not collected or analysed. This fact makes it impossible to perform a comparative analysis between the two levels of assistance (BLS and ALS). Furthermore, the broad spectrum of determinants that may have affected the capnometry values recorded, given the variability of values depending on factors such as the underlying cause of CPA. When patients suffer CPA due to asphyxiation, there is a tendency to present with higher capnometry values [19]. Also, the quality and depth of chest compressions [24], as well as the variability in ventilation in relation to the proficiency of the assisting personnel, may alter these values. These variables could be controlled for by filing the cause of OHCA as asphyxiation with the capnometry values, as well as implementing the use of devices as oscillometers, in order to manage the correlation between chest compression quality (depth and rate) and $EtCO_2$ values.

5. Conclusions

Initial capnometry values above or below 10 mmHg do not correlate with a survival increase during BLS, while BLS maneuvers and defibrillation performed by bystanders and first responders, seem to improve initial resuscitation results with regards to achieving ROSC and/or arriving to hospital alive. The typical patient assisted for CPA by our BLS units was a male aged 65 years or older.

AUTHOR CONTRIBUTIONS

FJCS and JMM designed the study. PMP, IUE and NMC performed the research, collected the data collection sheets.

TABLE 2. Variables related to capnometry values, experience (in years) of the emergency lifesaving technicians, CPR performed by bystanders, use of EAD, complications in airway management, ROSC, and admissions to hospital of patients who were alive.

VARIABLES	<15 years experience ELTs	>15 years experience ELTs	Chi-squared
			P Value[a]
$EtCO_2$			*P* = 0.642
<10 mmHg	7 (20.6%)	11 (32.4%)	
>10 mmHg	5 (14.7%)	11 (32.4%)	
Airway management complications	<15 years experience ELTs	>15 years experience ELTs	*P* = 0.811
Yes	9 (15.5%)	5 (8.6%)	
Not	24 (41.4%)	14 (24.1%)	
ROSC during CPR			*P* = 0.889
Yes	10 (17.2%)	5 (8.6%)	
Not	24 (41.4%)	16 (27.6%)	
Alive hospital admission			*P* = 0.976
Yes	7 (12.1%)	4 (6.9%)	
Not	27 (46.6%)	17 (29.3%)	
$EtCO_2$	Patient age <65 years	Patient age >65 years	*P* = 0.218
<10 mmHg	7 (20.6%)	5 (14.7%)	
>10 mmHg	8 (23.5%)	14 (41.2%)	
$EtCO_2$	ROSC YES	ROSC NO	*P* = 0.886
<10 mmHg	3 (8.8%)	9 (26.5%)	
>10 mmHg	6 (17.6%)	16 (47.1%)	
$EtCO_2$	Alive hospital admission YES	Alive hospital admission NO	*P* = 0.293
<10mmHg	1 (2.9%)	11 (32.4%)	
>10mmHg	5 (14.7%)	17 (50%)	
Airway management complications	ROSC YES	ROSC NO	$P \leq 0.000$[a]
Yes	1 (1.7%)	13 (22%)	
Not	13 (22%)	25 (42.4%)	
Airway management complications	Alive hospital admission YES	Alive hospital admission NO	$P \leq 0.000$[a]
Yes	1 (1.7%)	13 (22%)	
Not	9 (15.3%)	29 (49.2%)	
CPR Performed by bystanders	ROSC Yes	ROSC NO	$P \leq 0.000$[a]
Yes	12 (20.3%)	23 (39%)	
Not	3 (5.1%)	16 (27.1%)	
CPR Performed by bystanders	Alive hospital admission YES	Alive hospital admission NO	$P \leq 0.000$[a]
Yes	10 (16.9%)	25 (42.4%)	
Not	1 (1.7%)	18 (30.5%)	
Use of EAD	ROSC YES	ROSC NO	$P \leq 0.000$[a]
Yes	15 (25.4%)	35 (59.3%)	
Not	0 (0%)	4 (6.8%)	
Use of EAD	Alive hospital admission YES	Alive hospital admission NO	$P \leq 0.000$[a]
Yes	11 (18.6%)	39 (66.1%)	
Not	0 (0%)	4 (6.8%)	

[a] *Chi-square statistical significance <0.001.*

$EtCO_2$, End tidal carbon dioxide; ELT, Emergency lifesaving technician; ROSC, Return of spontaneous circulation; EAD, External automated defibrillator.

TABLE 3. Bivariate analysis between variables.

VARIABLES	Years experience of ELTs	ROSC
ROSC	0.636[b]	
Alive hospital admission	0.977[b]	
Airway management complications	0.534[b]	
$EtCO_2$	0.902[a]	0.325[b]
	0.905[c]	0.385[a]

$EtCO_2$, End tidal carbon dioxide; ELT, Emergency lifesaving technician; ROSC, Return of spontaneous circulation.
[a] *Pearson's r correlation.*
[b] *F-statistic of intergroup ANOVA, assuming equal variances according to Levene's test.*
[c] *Spearman's Rho.*

JMM provided help and advice on the analysis. FJCS and JMM analyzed the data. FJCS, JMM and JPT wrote the manuscript.

ETHICS APPROVAL AND CONSENT TO PARTICIPATE

Authorization was obtained from the Ethical Research Committee in Balearic Islands (IB 3607/18 PI). Informed Consent was requested from the patient once he could grant it freely and autonomously, or failing that to the family members, at the time of discharge from the Intensive Care Unit.

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CONFLICT OF INTEREST

The authors declare no conflict of interest.

DATA AVAILABILITY

The data used to support the findings of this study are available from the corresponding author upon request.

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