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Partial pressure of end-tidal carbon dioxide predict successful cardiopulmonary resuscitation on the field – a prospective observational study

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Abstract

Introduction

The prognosis among patients who suffer out-of-hospital cardiac arrest is poor. Higher survival rates have been observed only in patients with ventricular fibrillation who were fortunate enough to have basic and advanced life support initiated early after cardiac arrest. The ability to predict outcomes of cardiac arrest would be useful for resuscitation. Changes in expired end-tidal carbon dioxide levels during cardiopulmonary resuscitation may be a useful non-invasive predictor of successful resuscitation and survival from cardiac arrest, and help in the termination of cardiopulmonary resuscitation in the field.

Methods

This is a prospective observational study of 737 cases of victims who suffered sudden out-of-hospital cardiac arrest. The patients were intubated and the measurements of end-tidal carbon dioxide were performed. Data according to the Utstein criteria, demographic information, medical data and partial pressure of end-tidal carbon dioxide (petCO2) values were collected for each patient in cardiac arrest, by the emergency physician. We presumed that an end-tidal carbon dioxide level of 1.9 kPa (14.3 mmHg) or more after 20 minutes of standard advanced cardiac life support would predict restoration of spontaneous circulation (ROSC).

Results

Partial pressure of end-tidal carbon dioxide after 20 minutes of advanced life support averaged 0.92± 0.29 kPa (6.9mmHg ± 2.2 mmHg) in patients who did not have ROSC and 4.36 ±1.11 kPa (32.8 mmHg ± 9.1 mmHg) in those who did ($p<0,001$). End-tidal carbon dioxide values of 1.9 kPa (14.3 mmHg) or less discriminated between the 402 patients with ROSC and 335 patients without ROSC. When a 20-minute end-tidal carbon dioxide value of 1.9 kPa (14.3 mmHg) or less was used as a screening test to predict ROSC, the sensitivity, specificity, positive predictive value, and negative predictive value were all 100 percent.

Conclusions

Measurements of end-tidal carbon dioxide levels of more than 1.9 kPa (14.3 mmHg) after 20 minutes should be used to accurately predict ROSC. End-tidal carbon dioxide levels should be monitored during cardiopulmonary resuscitation and considered a useful prognostic value for determining the outcome of resuscitative efforts and termination of cardio-pulmonary resuscitation in the field.

Introduction

Despite all of the progress in reanimating patients in cardiac arrest over the last half century, resuscitation attempts usually fail to restore spontaneous circulation. Persistent discouraging low survival rates require reassessment of current strategies and capacities[1-5]. However, overall survival after out-of-hospital cardiac arrest is more commonly less than 3 percent [6-8]. Thus, the most common of all resuscitation decision after initiation remains the decision to stop. An entire library of research and guidelines for terminating resuscitative efforts has been developed in the past two decades and a number of clinical indicators has been used to determine when CPR efforts should be terminated [8-12]. Capnography (capnometry) represents potential clinical indicator of death, guiding decision to terminate resuscitative efforts[8,13]. We sought to evaluate the hypothesis that partial pressure of end-tidal carbon dioxide(petCO2) would predict no survival for patients in an independent cohort of patients with out-of-hospital cardiac arrest.

Materials and methods

737 cases of patients who suffered a sudden cardiac arrest in the field and were treated by a mobile emergency team were included in the prospective study. The data was obtained from the field-in emergency protocols in Maribor (approximately 200.000 inhabitants). The study was approved by the Ethical Board of the Ministry of Health of the Republic of Slovenia (59/05/00), granting waiver of the informed consent. Whenever possible, patients who regained consciousness or their relatives were informed of the study after enrollment.

Consistent with the European Union recommendations, we have a single emergency number, 112. In the Centre for Emergency Medicine Maribor there are two Prehospital emergency teams and two Basic life support teams equipped with the defibrillators. Additionally, in the period from April till October during daytime, there is a motorcycle rescuer with defibrillation capability included in Maribor; he and Prehospital emergency team are simultaneously dispatched and they »rendezvous« in the field.

Prehospital emergency team is an Advanced Life Support (ALS) unit of 3 members with adequately equipped road vehicle, including emergency physician and two register nurses or medical technicians.

BLS team is manned by two medical technicians or nurse and driver (paramedic). Motorcycle rescuer is manned by a register nurse or nurse. Prehospital emergency team is primarily routinely dispatched to the field in emergency situations (in case of presumed cardiac arrest, heart attacks, respiratory distress, cerebrovascular incident, trauma, delivery, poisoning etc). BLS and ALS are provided using a regional protocol that incorporates European Resuscitation Council standards and guidelines and clinical algorithms for cardiac resuscitation. After resuscitation, the patient is transferred to the Intensive Care Unit of University Clinical Center Maribor. Data to the Utstein criteria, demographic information, medical data and $petCO_2$ values were collected for each patient in cardiac arrest by the emergency physician. Hospital records were used for outcome analysis, and that also included assessment of cerebral performance category (CPC) by intensive care unit specialist. CPC score of 1 reflected good cerebral performance, CPC 2 and 3 moderate and severe cerebral disability, CPC 4 comatose, vegetative stage, and CPC 5 brain death.

All non-traumatic out-of-hospital cardiac arrest (OHCA) in adults older than 18 years in the years from January 1998 to December 2006, were included in the study. Exclusion criteria of the study were documented terminal illness, and severe hypothermia (< 30°C). The ROSC (return of spontaneous circulation) we defined in recommendation with Utstein style (»any ROSC« – palpabile pulse on carotide artery regardless of duration and ROSC with admission to hospital). In our analysis and comaparison we showed only patients with ROSC on admission to hospital (defined as having a stable blood pressure when the prehospital resuscitation team was dismissed by the ICU team).

An endotracheal tubus was immediately connected to the capnometer. We measured petCO2 continuously and recorded it during the resuscitation begining with intial postintubation petCO2 (first petCO2 value obtained) and ending with the final petCO2 value at admission to the hospital or termination of resuscitation attempts Measurements of petCO2 were done by sidestream method with infrared capnometer integrated in LIFEPACK 12 defibrillator monitor, Physio Control, Medtronic Inc,Redmond,USA or with BCI Capnocheck Model 20600A1,BCi International, Waukesha, Wisconsin,USA.

Continuous data were expresed as median with a range. Proportions were reported with 95% confidence interval. Analysis for caterogical variables were performed using -Chi-square test (with Yates correction, if appropriate) and exact Fisher test. Comparisons between groups were performed using t-test (normally distribution) and Mann-Whitney test (normality test failed).Sensitivita, specificity and positive (PPV) and negative (NPV) predictive values were calaculated using standard formulae.. For each value ROC curves were obtained The ROC curve depicts the relation between true-positive results (number of predicted deaths among those who actually died) and false-positive results (number of predicted deaths among those who actually survived) for each score. The greater the area under ROC curve, the better predicting value of petCO2 value.

Analyses of independent predictors for ROSC and survival from univariate analysis were performed using a multivariate logistic regression.

The null hypothesis was considered to be rejected at p-values less than 0.05 in all tests.. For statistical analysis we used computer software SPSS12.01 Inc.Chicago, Illinois, USA.

Results

In evaluation period our Centre had 1086 emergency interventions with absence of signs of circulation. Finally a group of 737 patients were resuscitated. Restoration of spontaneous circulation (ROSC) was obtained in 438 patients (59,4%), overall survival to hospital admission was 55% (402 patients) and 170 (23%) patients were discharged alive (Figure 1).

The univariate analysis for ROSC on admission showed that (Table 1) initial petCO2 , ventricular fibrillation or pulseless ventricular tachycardia as initial rhythm, witnessed arrest, performed bystander CPR, female sex and response time were associated with ROSC. Using the same method we found that bystander CPR, witnessed arrest, final petCO_2, initial petCO_2 and resposne time were associated with survival. The initial petCO_2 is higher in the group of the survived and the ROSC (3.17 kPa (23.8mmHg) ± 1.42kPa (10.7mmHg) vrs 2.34kPa (17.6 mmHg) ± 1.95kPa (14.7mmHg) and 3.13kPa (23,5mmHg)±1.65 kPa (12,4mmHg) vrs 2.54 kPa (19,1mmHg) ± 2.43kPa (18,3mmHg); p<0.001). The final petCO_2 (3.89kPa (29.3 mmHg)

± 1.12kPa (8.4mmHg) vrs 1.99 kPa (15.0 mmHg) ± 1.33kPa (10.0mmHg) and 3.64 kPa (27.4 mmHg) ± 0.94kPa (7.1mmHg) vrs 0.97kPa (7.3mmHg) ± 0.33kPa (2.5mmHg); p<0.001) is also considerably higher in the group of the survived and the ROSC (Table 2).

PetCO2 value was after 20 minutes of advanced life support averaged 0.91 kPa (6.8 mmHg) ± 0.29 kPa (2.2 mmHg) in patients without restoration of spontaneous circulation and 4.36kPa (32.8 mmHg) ± 1.11kPa (8.4 mmHg) in those with ROSC(p<0,001). End-tidal carbon dioxide value more than of 1.9kPa (14.3 mmHg) discriminated between the 402 patients with restoration of spontaneous circulation and 335 patients without ROSC. When end-tidal carbon dioxide value of 1.9kPa (14.3 mmHg) or less used as predicting test for death, the sensitivity, specificity, positive predictive value, and negative predictive value were all 100% (Table 3).

A 15-minute petCO2 value at 1.8kPa (13.5mmHg) had a sensitivity and negative predictive value 100 percent with high specificity and positive predictive value(98%).

In the patients with non-shockable initial rhythm (asy,PEA) we observed significant higher initial petCO2 in comparison with the group of shockable initial rhythm. On the contrary, in the group of patients who presented with VF/VT arrest there were a significant higher values of petCO2 from the first minute of CPR to the final value (admission to hospital or termination of CPR) (Table 4).

The values of petCO_2 in both groups (the group of skockable and the group of non-shockable initial rhythm) were significantly higher in patients with ROSC than in the patients without ROSC (except the petCO2 after 1 min of CPR in patients with asystole or PEA as initial rhythm). No patients with an initial, average, final, maximum petCO2 value of less than 1.33kPa (10 mmHg) was resuscitated (Table 5, Table 6).

After 20 min of CPR, petCO2 (regardless of initial rhythm) clearly discriminated between survivors and non-survivors on the field (admission to hospital) (Table 7, Table 8). In shockable group petCO2 value more than 1.5kPa (11.3 mmHg) (for a positive outcome) and non-shockable group value more than 1.90 kPa (14.3 mmHg) had a sensitivity, specificity, PPV, NPV value of 100% and AUROC was 1.

After 15 min of CPR, petCO2 value more than 1.8kPa (13.5 mmHg) had (in shockable and nonshockable group) sensitivity and NPV 100% with acceptable specificity, PPV and AUROC 1(Table 7 and Table 8).

With a cutoff point of 20-minute petCO2 value at 1.5kPa (13.5 mmHg) sensitivity and NPV were 100 in predicting discharge from hospital of patients with shockable intial rhythm.

With a cutoff point of petCO2 after 20 min of CPR at 2.1kPa (15.8 mmHg) the sensitivity and NPV were 100% in predicting discharge from hospital of patients with non-shockable initial rhythm (Table 10).

In multivariate analysis (Table 11) initial, average, 10-minute,15 minute, 20 minute, maximum and final value of petCO2, shockable initial rhythm (VF,VT), witnessed arrest, performed bystander CPR, female sex and arrival time were associated with improved ROSC.

Using the same method we found that bystander CPR, witnessed arrest, shockable initial rhythm, initial, average, 10- minute, 15- minute, 20- minute, maximum and final value of petCO2 and arrival time- were associated with improved survival (Table 12).

Discussion

In European perspective Scogvoll et al reported annual incidence of attempted CPR from 33 - 71 per 100000 inhabitants per year [14]. Sudden cardiac death accounts for approximately per day in the USA [5]. In the majority of cases, CPR and other treatment efforts are unsuccessful, and the patient is eventually pronounced dead. A number of clinical indicators can be used to determine when those efforts should be terminated [15 -18]. Morrison et al described a clinical decision rule for termination of resuscitation (TOR) designed to help determine whether to terminate emergency medical services resuscitative efforts for out-of-hospital cardiac arrest [12]. In this Canadian study investigators sought to validate they previously proposed prediction rule: termination of resuscitation should be considered if spontaneous circulation does not return before transport is initiated, if no AED shocks are given before transport is initiated, and if arrest was not witnessed by emergency personnel. This simple prediction rule has 99.5% PPV and specificity 90.2% and may be useful for supplementary guidance in the field [17]. However, a rule cannot determine, for example, how long to continue resuscitation efforts before declaring "no-ROSC " Decision about TOR continue to cause difficulties for healthcare professionals. Current guidelines provide some information on the underlying principles, but not include a objective, clear, numerical decision rule for TOR.

A number of animals and clinical studies suggests that the petCO2 can be used to determine when resuscitation be ceased. Several investigators suggested that the close correlation between petCO2 readings and cardiac output, stroke volume, coronary and cerebral perfusion pressure during CPR. Kalenda first reported a decrease in petCO2 in patients not resuscitated, and a significant rise in petCO2 in patients with ROSC [19].

Falk et al. founded that petCO2 decreased from mean of 1.4% pre-arrest to 0.4% after the onset of cardiac arrest It then increased with CPR and ROSC [20]. Sanders et al. found that the end-tidal carbon dioxide level predicted the success of resuscitation after in hospital and out-of-hospital cardiac arrest [21]. The average, initial, final, maximum and minimum value of petCO2 were all higher in resuscitated patients. No patients with an average petCO2 value of less than 1.33kPa (10 mmHg) was resuscitated.

Callaham and Barton found that the four patients who had initial and later petCO2 value of less than 1.33kPa(10 mmHg) were resuscitated [22]. This data and similar reports of ROSC after prolonged resuscitative attempts[23], with low petCO2 value may account for the reluctance of the scientific community to incorporate petCO2 in Utstein style report and resuscitation algorithms. In a landmark prospective study Levine et al observed 150 patients with cardiac arrest and measured petCO2 with a mainstream capnometer [8]. They compared 20-minute petCO2 and initial values and concluded that initial values are unreliable for the prognosis of mortality. The 20-minute values of petCO2 were promising and more reliable for the prognosis of mortality. Values less then 1.33kPa (10 mmHg) after 20 minutes of CPR were incompatible with survival and the authors are of the opinion that this could be helpful in deciding when to stop the resuscitation. In our previous studies, the relationship between petCO2 and prognosis in prehospital CPR was established [5,24]. In second study, we confirmed that petCO2 and MAP values are prognostic factors for the outcome of out-of-hospital cardaiac arrest. During a cardiac arrest, petCO2 can be considered an indirect parameter for the evaluation of cardiac output in prehospital monitoring together with MAP, when spontaneous circulation is restored.

Our study is the largest prospective study about predictive value of petCO2 measurement for ROSC and survival and include 737 victims of out of hospital sudden cardiac arrest.

In our study, we confirmed that bystander CPR, witnessed arrest, shockable initial rhythm, initial, average, 10- minute, 15- minute, 20- minute, maximum and final value of petCO2 and arrival time were associated with improved ROSC and survival.

We found that petCO2 value more than 1.9kPa (14.3 mmHg) measured after 20 min of resuscitation identified patients with ROSC with 100% sensitivity, specificity, PPV and NPV. No patients with an initial, average, final, maximum petCO2 value of less than 1.33kPa (10 mmHg) was resuscitated. With a cutoff point of 20-minute petCO2 value at 1.5kPa (13.5 mmHg) in patient with shockable initial rhythm and a cutoff point at 2.1kPa (15.8 mmHg) in patients with non-shockable initial rhythm sensitivity and NPV were 100 in predicting discharge from hospital .

In non-shockable rhythm we found higher initial value and lower value after 1 minute of CPR. In the previous our study we confirmed that the petCO2 was markedly elevated during the first minute of CPR in asphyxial cardiac arrest. This study therefore confirmed the results of the studies that used animal models in which cardiopulmonary arrest was induced by asphyxia. In this study the petCO2 values during CPR were initially high, then decreased to subnormal levels and then increased again to near-normal levels in patients with ROSC. This pattern of petCO2 changes is different from the pattern observed in cardiac arrest caused by VF, since cardiac arrest from VF results in an abrupt cessation of cardiac output and pulmonary blood flow.We concluded that, during the period of asphyxia, continued cardiac output prior to cardiac arrest permits continued delivery of CO2 to the lungs, which (in the absence of exhalation) results in higher alveolar CO_2. This is reflected as increased $petCO_2$ when ventilation is resumed [25].

Our results in patients with shockable initial rhythm confirmed forecast of Levine et al. [8], that the data from their study (petCO2 in patients with pulseless electrical activity) can be extended to all types of cardiac arrest. Sehra et al in a human model of ventricular fibrillation confirmed that petCO2 can predict severity of VF cardiac arrest and efficacy of CPR of this type cardiac arrest [26]. Our results in shockable group possible indirectly confirm 3-phase, time dependent concept of cardiac arrest due to ventricular fibrillation [26]. The value of petCO2 less of 1.5kPa (11.3 mmHg) after 20 minutes of CPR (or less of 1.8kPa (13.5 mmHg) after 15 minutes of CPR) are incompatible with ROSC. This time to coincide with the end of hemodynamic phase. Possible, these values present irreversible hemodynamic collapses with inadequate coronary or myocardial perfusion pressure or be perfusion pressures supplied too late (after the hemodynamic phase) with the irreversible tissue damage [27,28].

Our prehospital data, combined with findings from other investigators, provide strong support for a resuscitation threshold of initial 1.33kPa (10 mmHg) and 20-minute 1.9kPa (14.3 mmHg) in the field. The initial values of petCO2 which are not influenced by medications used in CPR and 20-min values which indicate the patients ”response” to resuscitation. We recommend initial and 20-min (final petCO2) to be ranked in Utstein style report. The idea is to assess the initial condition of the patient in non-traumatic normothermic cardiac arrest and to improve the petCO2 reliability in prognosis of survival in such patients.

Our results are potentially important especially to the system without physicians on emergency medical system units. The results of this study confirmed the pivotal role of values of petCO2 can play in the multifactorial decision to discontinue resuscitative efforts. Use of this findings would improve clinical prediction rules for TOR in the field and reduce the number of patients with cardiac arrest who undergo prolonged, futile resuscitation and reduce the transportation of patients with a refractory cardiac arrest to the hospital. For the health care system, there are fewer costs involved in TOR in the field than in the transferal of the patient to the hospital [12,29,30].

Conclusions

Measurements of partial pressure of end-tidal carbon dioxide should be used to accurately predict non-survival of patients with cardiopulmonary arrest. End-tidal carbon dioxide levels should be monitored during cardiopulmonary resuscitation and should be considered a useful prognostic value for determining the outcome of resuscitative efforts. Results can determine when advanced cardiac life support can be discontinued, decreasing the costs and dilemmas inside the resuscitation teams. The aim of this study is to incorporate end-tidal carbon dioxide monitoring into guidelines of advanced cardiac life- support algorithms and to be ranked in Utstein style report to provide better insight into condition of patients in cardiac arrest.

Key messages

- petCO2 level of 1.9kPa (14.3 mmHg) or less measured 20 minutes after the initiation of advanced cardiac life support accurately predicts death in patients with non-shockable initial rhythm in cardiac arrest.
- When a 20-minute petCO2 value of 1.5kPa (11.3 mmHg) or less was used as a screening test to predict death in patients with shockable rhythm, the sensitivity, specificity, positive and negative predictive value were all 100 percent.
- The value of petCO2 less of 1.5kPa (11.3 mmHg) after 20 minutes of CPR (or less of 1.8kPa (13.5 mmHg) after 15 minutes of CPR) are incompatible with ROSC.
- End-tidal carbon dioxide levels should be monitored during cardiopulmonary resuscitation and should be considered a useful prognostic value for determining the outcome of resuscitative efforts and termination of CPR.

Abbreviations

ALS - Advanced Life Support

APACHE II - acute physiology and chronic health evaluation

AUROC - area under receiver operating characteristic

ASY - asystole

CPC - cerebral performance category

CPR – cardiopulmonary resuscitation

EMS – emergency medical services

MAP –mean arterial pressure

NPV - negative predictive value

PEA - pulseless electrical activity

petCO2 – partial pressure of end-tidal CO2

PPV- positive predictive value

ROSC - restoration of spontaneous circulation

VF- ventricular fibrillation

VT - ventricular tachycardia

Se - sensitivity

Sp - specificity;

TOR- termination of resuscitation

Competing interests

The authors declare that they have no competing interests

Authors' contributions

MK participated in design of study, collection and analysis of data and helped to draft the manuscript. MK participated in design of study, collection and statistical analysis of data. PK participated in design of study and helped to draft the manuscript ŠG participated in design of study, collection and analysis of data, revised the manuscript for important intellectual content and helped to draft the manuscript. All authors read and approved the final version of the manuscript.

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Table 1. Clinical and demographic characteristics for 737 of cardiac arrest patients, according to immediate outcome (ROSC with hospital admission)

	Death in the field (N=335)	ROSC with hospitalization (N=402)	p-value
Male sex (%) *	242 (72.2%)	253 (62.9%)	p=0.007
Age (years)#	62.7 +/-15.8	58.8 +/12.8	p=0.049
Initial shockable(VF/VT) rhythm*	92 (27.5%)	212(52.7%)	p<0.001
Witnessed arrests*	176 (52.5%)	294 (73.1%)	p=0.001
Bystander CPR*	41 (12.2%)	132 (32.8%)	p<0.001
Initial petCO_2 kPa(mmHg)#	2.6 +/-2.4 (19.6 +/- 18.1)	3.1 +/-1.6 (23.5+/-12.4)	p<0.001
Final petCO_2 (mmHg)#	0.9+/-0.3 (7.3 +/- 2.5)	3.5+/-0.9 (27.4 +/- 7.1)	p<0.001
Response time(min)#	11.2 +/- 4.3	7.8 +/-3.9	p<0.001

VF, ventricular fibrillation; VT, ventricular tachycardia; CPR, cardiopulmonary resuscitation; petCO_2, partial end-tidal pressure.* Fisher test # Wilcoxon rank sum test

Table 2. Clinical and demographic characteristics for the 737 cardiac arrest patients, according to survival (discharge from hospital)

	Death (in the field and in hospital) (N=567)	Survivors (discharge from hospital) (N=170)	p-value
Male sex (%) *	384(67.7%)	111(65.3%)	$p=0.224$
Age(years)#	61.2 +/14.7	60.2 +/-13.3	$p=0.861$
Initial shockable rhythm (VF+VT)(%)*	209 (36.9%)	95(55.8%)	$p=0.206$
Witnessed arrests* (%)	314(55.4%)	160(94.1%)	$p<0.001$
Bystander CPR* (%)	86 (15.2%)	88 (51.8%)	$p<0.001$
Initial $petCO_2$,kPa (mmHg)#	2.4+/-1.9 (17.6.0 +/- 14.7)	3.1+/-1.4 (23.8 +/-10.7)	$p<0.001$
Final $petCO_2$ kPa(mmHg)#	1.9+/-1.4 (15.0 +/-10.0)	3.9+/-1.1 (29.3 +/- 8.4)	$p<0.001$
Response time (min)#	12.7 +/- 4.4	6.3 +/- 3.2	$p<0.001$

VF, ventricular fibrillation; VT, ventricular tachycardia; $petCO_2$, partial end-tidal pressure.

* Fisher test # Wilcoxon test

Table 3. Sensitivity, specificity, PPV, NPV and AUROC for various values of petCO2 and duration of CPR for prediction of ROSC for all patients with cardiac arrest

petCO2	Cutoff kPa [mmHg]	N	Min-Max kPa [mmHg]	Mean±std kPa [mmHg]	Se [%]	Sp [%]	PPV [%]	NPV [%]	AUROC (95% CI)
initial	≤1.3 ≤10	168	0.0-1.3 0.0-10	0.68±0.34 5.1±2.5	100	50	71	100	0.68 (0.63 - 0.72)
	>1.3 >10	569	1.4-8.7 10.1-65.4	3.52±1.93 26.3±14.5					
0-10 min	≤1.6 ≤12.1	306	0.3-1.6 2.3-12.1	0.96±0.34 7.2±2.6	100	91	93	100	0.99 (0.99 - 1.00)
	>1.6 >12.1	431	1.7-5.6 12.2-42.1	2.79±0.82 20.9±0.8					
10 min	≤1.3 ≤9.8	202	0.3-1.3 2.3-9.8	0.85±0.31 6.4 ±2.1	100	60	75	100	0.99 (0.98 - 0.99)
	>1.3 >9.8	535	1.4-7.2 9.9-54.2	2.89±1.09 21.7±8.2					
11-15 min	≤1.7 ≤12.8	333	0.4-1.7 3.1-12.8	0.99±0.30 7.6±2.2	100	99	99	100	1.00 (0.99 - 1.00)
	>1.7 >12.8	404	1.8-5.5 12.8-41.4	3.19±0.77 23.9±4.8					
15 min	≤1.8 ≤13.6	328	0.2-1.8 1.5-13.5	1.11±0.39 8.4±2.8	100	98	98	100	0.99 (0.99 - 1.00)
	>1.8 >13.6	409	1.9-7.7 13.6-57.9	3.65±0.98 27.8±7.4					
20 min	≤1.9 ≤14.3	335	0.3-1.9 2.3-14.3	0.92±0.29 6.8±2.1	100	100	100	100	1.00 (1.00 - 1.00)
	>1.9 >14.3	402	2.1-7.8 14.4-58.7	4.36±1.11 33.1±8.4					
Maximal	≤2.3 ≤17.3	293	0.7-2.3 5.3-17.3	1.58±0.34 12.1 ±2.6	100	87	91	100	0.99 (0.99 - 1.00)
	>2.3 >17.3	444	2.4-10.7 (18.1-80.5)	5.12±1.57 38.4±11,9					
Final	≤1.7 ≤12.8	335	0.2-1.7 1.7-12.8	0.98±0.33 7.4 ±3.2	100	99	99	100	1.00 (1.00 - 1.00)
	>1.7 >12.8	402	1.9-6.6 14.3-49.7.	0.98±0.33 27.8±7.2					

Se indicates sensitivity; Sp, specificity; PPV, positive predictive value; NPV, negative predictive value; AUROC, area under receiver operating characteristic.

Table 4. Comparison of characteristics and values of petCO2 between shockable(VF,VT) and non-shockable (ASY,PEA) initial rhythm for patients with cardiac arrest

	Shockable (N=304)	Non-shockable (N=433)	p-value
Age (years)	59,5 +/- 11.9	60.1 +/- 12.9	0.55
Arrival(min)	8.6 +/- 4.5	9.9 +/- 4.3	0.03
(min –max)	(1- 22)	(2 -29)	
Initial petCO2 kPa(mmHg)	2.2+/- 1.3 (16.6 +/- 9.8)	3.4+/-2.4 (25.6 +/-18.1)	<0.001
1 min petCO2 kPa(mmHg)	3.3+/-1.4 (24.8 +/- 10.5)	2.8+/-1.5 (21.1 +/- 11.3)	< 0.001
Average petCO2 (0-10 min) kPa (mmHg)	2.3+/-1.1 (17.3 +/-8.3)	1.8+/-1.2 (13.5 +/- 0.9)	< 0.001
10 min petCO2 kPa (mmHg)	2.7+/-1.3 (20.3 +/- 10)	2.1+/-1.3 (15.8 +/- 10)	< 0.001
11 -15 min petCO2 kPa (mmHg)	2.5 +/-1.2 (18.8 +/- 9.1)	1.9+/-1.2 (14.3 +/- 9.7)	< 0.001
15 min petCO2kPa (mmHg)	2.9+/-1.5 (21.8 +/- 11.3)	2.2+/-1.4 (16.5 +/- 10.5)	< 0.001
20 minutes petCO2 kPa (mmHg)	3.3+/-1.8 (24.8 +/- 13.5)	2.4+/-1.9 (18.1 +/- 14.3)	< 0.001
Max petCO2 kPa(mmHg)	4.2+/-2.1 (31.6 +/- 15.8)	3.3+/-2.1 (24.8 +/- 15.8)	< 0.001
Final petCO2 kPa(mmHg)	2.9+/-1.5 (21.8 +/- 11.3)	2.1+/-1.5 (15.8 +/- 11.3)	< 0.001

$PetCO_2$ indicates partial end-tidal pressure; VF, ventricular fibrillation; VT, ventricular tachycardia; ASY, asystole; PEA, pulseless electrical activity.

Table 5. Comparison of characteristics and values of petCO2 between patients with ROSC and without ROSC in shockable (VF and VT) initial rhythm in cardiac arrest

	ROSC (N=211)	Non –ROSC (N=93)	p-value
Age (years)	58.6 +/-10.9	61.8 +/-13.6	0.03
Initial petCO2,kPa (mmHg)	2.7+/-1.1 (20.3 +/- 9.2)	1.8+/-1.3 (13.5 +/- 10)	<0.001
1min petCO2, kPa (mmHg)	3.6+/-1.3 (27.1 +/- 10)	2.6+/-1.4 (19.6+/- 11)	< 0.001
Average petCO2 (0-10 min),kPa (mmHg)	2.9+/-0.8 (21.8 +/- 6.1)	1.1+/-0.4 (8.3 +/- 3.1)	< 0.001
10 min petCO2 kPa(mmHg)	3.3+/-0.9 (24.8 +/-6.8)	1.2+/-0.5 (9.1 +/- 4.2)	<0.001
11 -15 min petCO2 kPa(mmHg)	3.2+/-0.7 (24.1 +/- 5.1)	0.9+/-0.3 (6.8 +/- 2.7)	<0.001
15 min petCO2 ,kPa (mmHg)	3.7+/-0.9 (27.9 +/- 6.8)	1.1+/-0.4 (8.3 +/- 3.4)	<0.001
20 minutes petCO2 kPa(mmHg)	4.3+/-1.1 (32.3 +/- 8.7)	0.9+/-0.3 (7.1 +/- 2.6)	<0.001
Max petCO2 kPa(mmHg)	5.3+/-1.5 (39.9 +/- 11.3)	1.7+/-0.6 (12.8 +/- 5.5)	<0.001
Final petCO2 kPa(mmHg)	3.7+/-0.9 (27.8 +/- 6.6)	1.0+/-0.3 (7.5 +/- 2.7)	<0.001

$PetCO_2$ indicates partial end-tidal pressure; ROSC, restoration of spontaneous circulation; VF, ventricular fibrillation; VT, ventricular tachycardia.

Table 6. Comparison of characteristics and values of petCO2 between patients with ROSC and without ROSC in non-shockable (asystole and PEA) initial rhythm in cardiac arrest

	ROSC (N= 191)	Non –ROSC (N=242)	p-value
Age (years)	59.6 +/-12.9	60.5 +/-12.9	0.45
Initial petCO2 kPa(mmHg)	3,7+/-1.9 (27.8 +/- 14.3)	3.1+/-2.6 (23.3 +/- 19.6)	0.02
1min petCO2 kPa(mmHg)	2.8+/-1.6 (21.1 +/- 13.2)	2.7+/-1.4 (20.3 +/- 11.2)	0.44
Average petCO2 (0-10 min) kPa(mmHg)	2.8+/-0.9 (22.2 +/- 6.8)	1.1+/-0.4 (7.8 +/- 3.8)	< 0.001
10 min petCO2 kPa(mmHg)	3.3+/-1.1 (24.8 +/-7.8)	1.2+/-0.5 (8.2 +/- 3.6)	<0.001
Average 11 -15 min petCO2 kPa(mmHg)	3.2+/-0.8 (24.1 +/- 6.3)	1.0+/-0.3 (7.7 +/- 2.6)	<0.001
15 min petCO2 kPa(mmHg)	3.6+/-0.9 (27.1 +/- 7.2)	1.1+/-0.4 (7.9 +/- 3.5)	<0.001
20 minutes petCO2 kPa(mmHg)	4.4+/-1.2 (33.1 +/- 9.1)	0.9+/-0.3 (9.2 +/- 2.7)	<0.001
Max petCO2 kPa(mmHg)	5.4+/-1.5 (40.1 +/- 12.3)	1.8+/-0.6 (15.6 +/- 4.4)	<0.001
Final petCO2 kPa(mmHg)	3.6+/-0.9 (27.3 +/- 7.1)	0.9+/-0.3 (7.3 +/- 2.5)	<0.001

$PetCO_2$ indicates partial end-tidal pressure; ROSC, restoration of spontaneous circulation; PEA, pulseless electrical activity.

Table 7. Sensitivity, specificity, PPV, NPV and AUROC for various values of petCO2 and duration of CPR for prediction of ROSC in patients with shockable (VF,VT) initial rhythm in cardiac arrest

			ROSC						
petCO2	Cutoff kPa [mmHg]	N	Min-Max kPa [mmHg]	Mean±std kPa [mmHg]	Se [%]	Sp [%]	PPV [%]	NPV [%]	AUROC (95%CI)
initial	≤1.3 (10)	71	0.0-1.3 (0.0-10)	0.69±0.3(5.2 ±2.6)	100	76	91	100	0.93 (0.86 - 0.97)
	>1.3 (10)	233	1.4-8.7(10.1-65.4)	2.59±1.08(19.6±8.3)					
0-10 min (average)	≤1.6(12.1)	86	0.3-1.6(2.8-12.1)	0.96± 0.33(7.22±3.1)	100	92	97	100	0.99 (0.99 - 1.00)
	>1.6(12.1)	218	1.7-4.8(12.2-39.1)	2.83± 0.77(21.1±5.8)					
10 min	≤1.5(11.3)	72	0.3-1.5(2.6-11.3)	0.96±0.37(7.2±2.9)	100	77	91	100	0.99 (0.98 - 0.99)
	>1.5(11.3)	232	1.6-5.8(11.4-43.6)	3.17±0.96(24.1±7.3)					
11-15 min (average)	≤1.6(12.1)	93	0.4-1.6(3.7-12.1)	0.99± 0.28(7.5±2.1)	100	100	100	100	1.00 (1.00 - 1.00)
	>1.6(12.1)	211	1.8-5.5(13.5-41.4)	3.22-0.74(24.1±8.3)					
15 min	≤1.8(13.5)	92	0.2-1.8(1.6-13.5)	1.11± 0.39(7.9±2.9)	100	99	100	100	1.00 (1.00 - 1.00)
	>1.8(13.5)	212	1.9-7.7(13.6-59.3)	3.71± 0.99(27.8±7.3)					
20 min	≤1.5(11.3)	93	0.3-1.5(2.8-11.3)	0.95± 0.26(7.3±2.2)	100	100	100	100	1.00 (1.00 - 1.00)
	>1.5(11.3)	211	2.1-7.3(11.4-54.9)	4.33± 1.11(32.3±7.9)					
max	≤2.3(17.3)	83	0.7-2.3(5.26-17.3)	1.56± 0.34(13.2±3.4)	100	89	95	100	0.99 (0.90 - 1.00)
	>2.3(17.3)	221	2.4-10.6 (17.4-79.7)	5.23+/-1.5(39.3±11)					
Final	≤1.5(11.3)	93	0.3-1.5(2.6-11.3	1.0± 0.32(7.5±1.9)	100	100	100	100	1.00 (1.00 - 1.00)
	>1.5(11.3)	211	1.9-6.3(11.3-47.4)	3.69± 0.94(27.8±7.1)					

VF, ventricular fibrillation; VT, ventricular tachycardia; Se indicates sensitivity; Sp, specificity PPV, positive predictive value; NPV, negative predictive value; AUROC, area under receiver operating characteristic; $petCO_2$, partial end-tidal pressure; CPR, cardiopulmonary resuscitation; ROSC, restoration of spontaneous circulation.

Table 8. Sensitivity, specificity, PPV, NPV and AUROC for various values of petCO2 and duration of CPR for prediction of ROSC in patients with non- shockable (ASY, PEA) initial rhythm in cardiac arrest

	ROSC								
petCO2	Cutoff kPa [mmHg]	N	Min-Max kPa [mmHg]	Mean±std kPa [mmHg]	Sens [%]	Spec [%]	PPV [%]	NPV [%]	AUROC (95%CI)
Initial	≤1.3(10)	97	0.0-1.3 (0.0-10)	0.66± 0.32(5.1±2.3)	100	40	57	100	0.61 (0.56 - 0.67)
	>1.3(10)	336	1.4-8.4 (10.1-63.2)	4.17± 2.2(30.8±15.8)					
0-10 min	≤1.6(12.1)	220	0.4-1.6 (3.4-12.1)	0.97± 0.34 (7.3±2.2)	100	91	90	100	0.99 (0.98 - 0.99)
	>1.6(12.1)	213	1.7-5.6 (12.2-42.1)	2.74± 0.87(20.6±6.7)					
10 min	≤1.3(11)	147	0.3-1.3 (3.6-11)	0.86± 0.32 (6.9±2.1)	100	61	67	100	0.98 (0.97 - 0.99)
	>1.3(11)	286	1.4-7.2 (11.1-54.2)	2.74± 1.14 (21.1±7.9)					
11-15 min	≤1.7(12.8)	240	0.4-1.7(3.7-12.8)	0.99± 0.31 (7.3±2.6)	100	99	99	100	1.00 (0.99 - 1.00)
	>1.7(12.8)	193	1.9-5.1 (12.9-38.4)	3.15± 0.79 (24.1±7.1)					
15 min	≤1.8(13.5)	236	0.3-1.8 (2.3-13.5)	1.11± 0.39 (7.7±3.3)	100	98	97	100	0.99 (0.99 - 1.00)
	>1.8(13.5)	197	1.9-6.1 (13.6-45.9)	3.58± 0.97 (27.1±7.4)					
20 min	≤1.9(14.3)	242	0.3-1.9 (2.2-14.3)	0.91± 0.29 (7.3±2.4)	100	100	100	100	1.00 (1.00 - 1.00)
	>1.9(14.3)	191	2.1-7.8 (14.4-58.7)	4.38± 1.17 (33.1±7.6)					
Max	≤2.3(17.3)	210	0.8-2.3 (6.7-17.3)	1.59± 0.35 (13.2±3.4)	100	87	86	100	1.00 (1.00 - 1.00)
	>2.3(17.3)	223	2.4-10.7 (17.4-80.5)	5.0±1.61 (37.6±15.8)					
Final	≤1.6(12.3)	239	0.2-1.6 (1.8-12.3)	0.97± 0.33 (7.2±2.8)	100	99	98	100	1.00 (1.00 - 1.00)
	>1.6(12.3)	194	1.0-6.6 (12.4-49.6)	3.59± 0.98 (27.1±7.4)					

ASY, asystole; PEA, pulseless electrical activity; Se indicates sensitivity; Sp, specificity PPV, positive predictive value; NPV, negative predictive value; AUROC, area under receiver operating characteristic; $petCO_2$, partial end-tidal pressure; CPR, cardiopulmonary resuscitation; ROSC, restoration of spontaneous circulation.

Table 9. Sensitivity,specificity, PPV, NPV and AUROC for various values of petCO2 and duration of CPR for prediction of survival in patients with shockable (VF,VT) initial rhythm in cardiac arrest

petCO2	**Cutoff kPa [mmH]**	**N**	**Minimum-Maximum kPa [mmHg]**	**Mean±std kPa [mmHg]**	**Se [%]**	**Sp [%]**	**PPV [%]**	**NPV [%]**	**AUROC (95%CI)**
initial	≤1.3(10)	71	0.0-10(0.0-1.3)	5.3±1.9(0.69±0.35)	100	34	40	100	0.73 (0.67-0.78)
	>1.3(10	233	10.1-65.4(1.4-8.7)	19.5±6.8(2.59±1.07)					
0-10 min	≤1.7(12.8)	91	0.3-1.7(2,5-12.8)	0.99±0.36(7.5±2.1)	100	43	44	100	0.82 (0.78-0.87)
	>1.7(12.8)	213	1.8-4.8(12.9-36.1)	2.86± 0.76(21.8±5.2)					
10 min	≤1.6(12.1)	82	0.3-1.6(2.3-12.1)	1.04± 0.41(7.6±3.4)	100	39	42	100	0.82 (0.78-0.87)
	>1.6(12.1)	222	1.7-5.8(12.2-43.6)	3.24± 0.93(24.1±7.1)					
11-15 min	≤1.6(12.1)	93	0.4-1.6(3.3-12.2)	0.99± 0.28(7.4±2.3)	100	44	45	100	0.78 (0.73-0.83)
	>1.6(12.1)	211	1.8-5.5(12.3-41.4)	3.22± 0.74(24.4±4.9)					
15 min	≤1.9(14.3)	94	0.2-1.9(1.9-14.3)	1.25± 0.41(7.9±2.9)	100	45	45	100	0.78 (0.73-0.83)
	>1.9(14.3)	210	2.0-7.7(14.4-57.9)	3.73±0.98 (27.8±7.1)					
20 min	≤1.5(11.3)	93	0.3-1.5(2.8-11.3)	0.95± 0.26(7.2±2.1)	100	44	45	100	0.78 (0.72-0.83)
	>1.5(11.3)	211	2.1-7.3(11.4-54.9)	4.33± 1.11(32.3±7.8)					
max	≤2.5(18.8)	89	0.7-2.5(0.7-18.8)	1.62± 0.39(12.4±3.3)	100	42	44	100	0.81 (0.76-0.86)
	>2.5(18.8)	215	2.6-10.6(18.9-79.7)	5.3± 1.48(39.9±11.5)					
Final	≤1.5(11.3)	93	0.3-1.5(2.7-11.3)	1.0± 0.32(7.5 ±3.1)	100	44	45	100	0.78 (0.73-0.83)
	>1.5(11.3)	211	1.9-6.3(11.4-47.4)	3.69± 0.94(27.8±6.9)					

VF, ventricular fibrillation; VT, ventricular tachycardia; Se, sensitivity; Sp, specificity PPV, positive predictive value; NPV, negative predictive value; AUROC, area under receiver operating characteristic; $petCO_2$, partial end-tidal pressure; CPR, cardiopulmonary resuscitation.

Table 10.Sensitivity,specificity,PPV,NPV and AUROC for various values of petCO2 and duration of CPR for prediction of survival in patients with non-shockable(ASY,PEA) initial rhythm in cardiac arrest.

petCO2	Cutoff kPa [mmH]	N	Minimum-Maximum k.Pa [mmHg]	Mean±std kPa [mmHg]	**Se [%]**	**Sp [%]**	**PPV [%]**	**NPV [%]**	**AUROC (95%CI)**
initial	≤1.3(10)	97	0.0-1.3(0.0-10)	0.66± 0.32(5.1±1.9)	100	27	23	100	0.58 (0.52-0.63)
	>1.3(10)	336	1.4-8.4(10.1-63.2)	4.17- 2.12(30.9±15.8)					
0-10 min	≤1.7(12.8)	229	0.4-1.7(3.5-12.8)	0.99± 0.36(7.1±3.3)	100	64	37	100	0.88 (0.84-0.91)
	>1.7(12.8)	204	1.8-5.6(12.9-42.1)	2.79± 0.86(21.5±6.2)					
10 min	≤1.6(12.1)	199	0.3-1.6(2.2-12.1)	1.03± 0.38(7.6±3.1)	100	56	32	100	0.87 (0.83-0.91)
	>1.6(12.1)	234	1.7-7.2(12.2-54.2)	3.02± 1.08(22.6±6.5)					
11-15 min	≤1.7(12.8)	239	0.4-1.7(3.4-12.8)	0.99± 0.31(7.3±2.8)	100	67	39	100	0.86 (0.83-0.90)
	>1.7(12.8)	194	1.4-5.1(12.9-38.4)	3.14± 0.81(23.3±6.7)					
15 min	≤1.9(14.3)	241	0.3-1.9(2.4-14.3)	1.12± 0.41(7.9±3.8)	100	67	39	100	0.87 (0.84-0.91)
	>1.9(14.3)	192	2.1-6.1(14.4-45.9)	3.62± 0.94(28.6±7.5)					
20 min	≤2.1(15.8)	242	0.3-2.1(2.3-15.8)	0.91±0.31(7.2±2.2)	100	68	40	100	0.87 (0.84.0.91)
	>2.1(15.8)	190	2.3-7.8(15.9-58.7)	4.39-1.11(33.1±7.7)					
max	≤2.8(21.1)	231	0.8-2.8(6.1-21.1)	1.68± 0.44(13.4±3.5)	100	65	38	100	0.89 (0.86-0.92)
	>2.8(21.1)	202	2.9-10.7(21-80.5)	5.26± 1.48(39.1±12.2)					
Final	≤1.6(12.1)	240	0.2-1.6(1.9-12.1)	0.97± 0.33(6.9 ±2.7)	100	67	39	100	0.87 (0.84-0.91)
	>1.6(12.1)	193	1.9-6.6(12.2-49.6)	3.06± 0.97(27.1±7.2)					

ASY, asystole; PEA, pulseless electrical activity; Se, sensitivity; Sp, specificity PPV, positive predictive value; NPV, negative predictive value; AUROC, area under receiver operating characteristic; petCO$_2$, partial end-tidal pressure; CPR, cardiopulmonary resuscitation

Table 11. Variables associated with ROSC in cardiac arrest

Variables	Odds ratio	95% confidence interval	P - value
Intial Rhythm (VF/VT)	2.13	1.17 - 4.22	0.02
Female sex	1.58	1.14 – 1.87	0.04
Time arrival	1.69	1.37 – 2.56	0.01
Witness	1.65	1.29– 3.14	0.02
Bystander CPR	3.26	1.89 – 8.51	0.01
Initial $petCO_2$	21.68	9.72 - 38.37	< 0.0001
Average petCO2	19.48	7.53 – 33.86	<0.001
10 min petCO2	14.37	6.65 -28.63	<0.001
15 min petCO2	17.41	7.62 – 24.57	<0.001
20min petCO2	24.86	10.11 – 42.73	<0.001
Max petCO2	12.23	4.83 - 23.64	<0.001
Final petCO2	18.07	6.93 – 28.34	<0.001

VF, ventricular fibrillation; VT, ventricular tachycardia; Se indicates sensitivity; $petCO_2$, partial end-tidal pressure; CPR, cardiopulmonary resuscitation; ROSC, restoration of spontaneous circulation

Table 12. Variables associated with survival in cardiac arrest

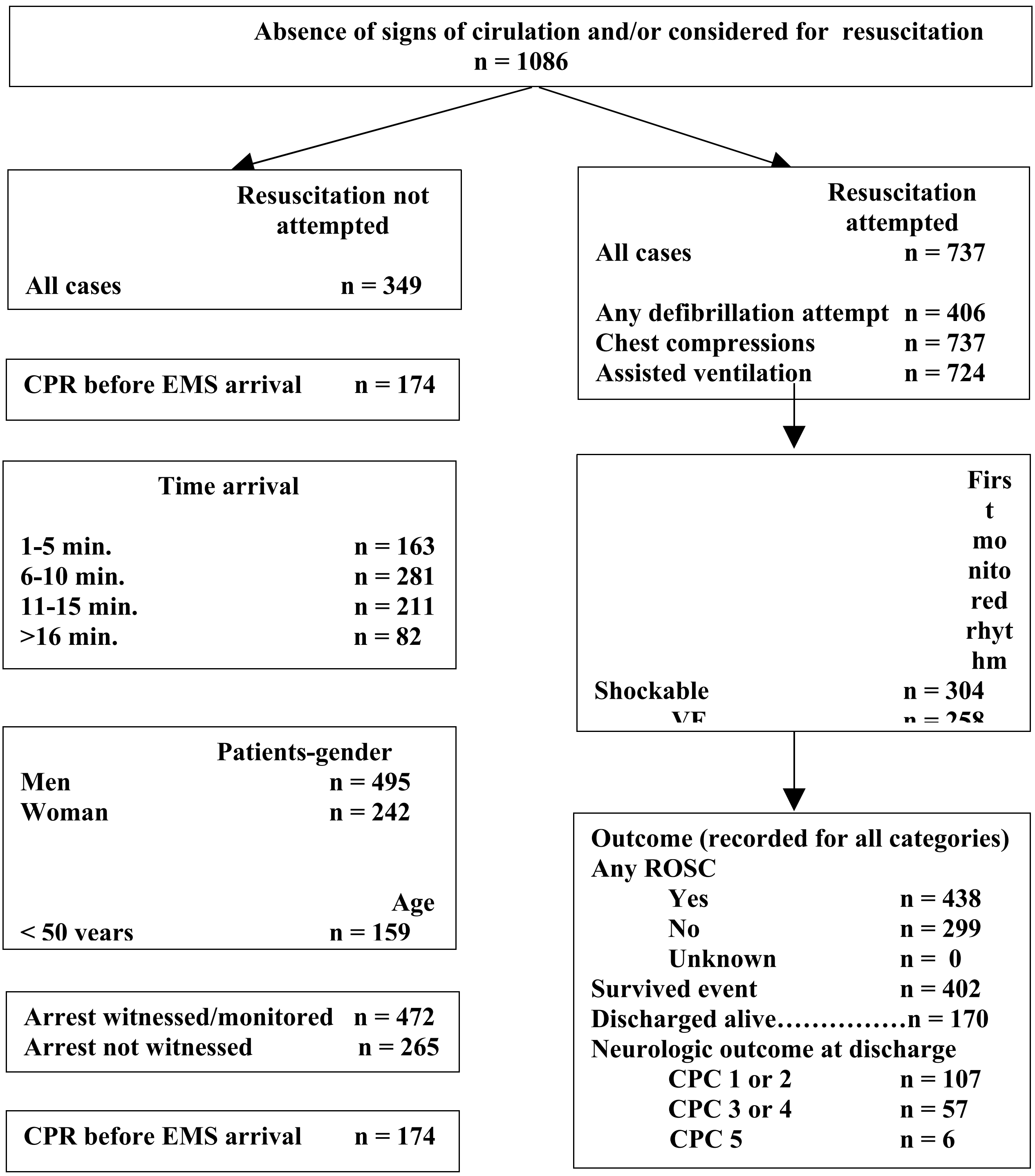
Variables	Odds ratio	95% confidence interval	p – value
Initial rhythm (VF/VT)	1.86	1.26 – 3.11	<0.001
Arrival time	1.39	1.33 – 1.60	= 0.01
Witness	9.98	2.89 - 34.44	< 0.0001
Bystander CPR	5.05	2.24 – 11.39	< 0.0001
Intial $petCO_2$	1.93	1.48 – 3.75	0.018
Average petCO2	2.31	1.45 - 4.86	<0.001
10 min petCO2	2.11	1.27 – 4.16	0.001
15 min petCO2	2.47	1.33 – 5.21	<0.001
20 min petCO2	3.85	1.71 – 8.34	<0.001
Final $petCO_2$	2.37	1.67 – 3.37	< 0.001

VF, ventricular fibrillation; VT, ventricular tachycardia; $petCO_2$, partial end-tidal pressure; CPR, cardiopulmonary resuscitation; ROSC, restoration of spontaneous circulation.

Figure 1.

Utstein reporting template for out-of-hospital cardiac arrest obtained in a eight years period. CPR indicates cardiopulmonary resuscitation; EMS, emergency medicine services; VF, ventricular fibrillation; VT, ventricular tachycardia; PEA, pulseless electrical activity; ROSC, restoration of spontaneous circulation; CPC, cerebral performance category.

Figure 1. Utstein reporting template for out-of-hospital cardiac arrest obtained in a eight years period



CPR indicates cardiopulmonary resuscitation; EMS, emergency medicine services; VF, ventricular fibrillation; VT, ventricular tachycardia; PEA, pulseless electrical activity; ROSC, restoration of spontaneous circulation; CPC, cerebral performance category.