# End-Tidal CO$_2$ as a Predictor of Survival in Out-of-Hospital Cardiac Arrest

Marc Eckstein, MD, MPH;[1,2] Lorien Hatch, MA;[1] Jennifer Malleck, MS;[1] Christian McClung, MD;[1] Sean O. Henderson, MD[1,3]

1. Department of Emergency Medicine, Keck School of Medicine of the University of Southern California, Los Angeles, California
2. Los Angeles Fire Department, Los Angeles, California USA
3. Department of Preventive Medicine, Keck School of Medicine of the University of Southern California, Los Angeles, California USA

Correspondence:
Marc Eckstein, MD, MPH
Department of Emergency Medicine
LAC/USC Medical Center
1200 N. State Street, Room 1011
Los Angeles, CA 90033
Tel: 213-978-3741
E-mail: eckstein@usc.edu

## Abstract

**Objective:** The objective of this study was to evaluate initial end-tidal CO$_2$ (EtCO$_2$) as a predictor of survival in out-of-hospital cardiac arrest.

**Methods:** This was a retrospective study of all adult, non-traumatic, out-of-hospital, cardiac arrests during 2006 and 2007 in Los Angeles, California. The primary outcome variable was attaining return of spontaneous circulation (ROSC) in the field. All demographic information was reviewed and logistic regression analysis was performed to determine which variables of the cardiac arrest were significantly associated with ROSC.

**Results:** There were 3,121 cardiac arrests included in the study, of which 1,689 (54.4%) were witnessed, and 516 (16.9%) were primary ventricular fibrillation (VF). The mean initial EtCO$_2$ was 18.7 (95%CI = 18.2–19.3) for all patients. Return of spontaneous circulation was achieved in 695 patients (22.4%) for which the mean initial EtCO$_2$ was 27.6 (95%CI = 26.3–29.0). For patients who failed to achieve ROSC, the mean EtCO$_2$ was 16.0 (95%CI = 15.5–16.5). The following variables were significantly associated with achieving ROSC: witnessed arrest (OR = 1.51; 95%CI = 1.07–2.12); initial EtCO$_2$ >10 (OR = 4.79; 95%CI = 3.10–4.42 ); and EtCO$_2$ dropping <25% during the resuscitation (OR = 2.82; 95%CI = 2.01–3.97).

The combination of male gender, lack of bystander cardiopulmonary resuscitation, unwitnessed collapse, non-vfib arrest, initial EtCO$_2$ ≤10 and EtCO$_2$ falling > 25% was 97% predictive of failure to achieve ROSC.

**Conclusions:** An initial EtCO$_2$ >10 and the absence of a falling EtCO$_2$ >25% from baseline were significantly associated with achieving ROSC in out-of-hospital cardiac arrest. These additional variables should be incorporated in termination of resuscitation algorithms in the prehospital setting.

## Introduction

Several studies of patients experiencing out-of-hospital cardiac arrest suggest that there are variables that are highly predictive of achieving return of spontaneous circulation (ROSC) in the field, namely ventricular fibrillation as the presenting rhythm, bystander cardiopulmonary resuscitation (CPR), witnessed arrest, and time to first defibrillation.[1] End-tidal CO$_2$ (EtCO$_2$) has been suggested as a further predictor of cardiac arrest outcome for more than a decade, but only recently has become used widely in the field by emergency medical services (EMS) personnel or in the emergency department.[2–5]

EtCO$_2$ reflects the efficiency of CPR, and correlates well with cardiac output. It is easy to perform, non-invasive, and allows for a rapid assessment that provides valuable information in regard to survival with advanced cardiac live support (ACLS) interventions. The first reference to the utility of EtCO$_2$ as both an aid to CPR as well as a prognostic aid was made almost a half-century ago in Germany.[6] Since then, the technology associated with monitoring EtCO$_2$ has improved to the point where this information is available on patients receiving resuscitation regardless of where the event occurs.[6–8] This paper describes using EtCO$_2$ as a predictor of survival in a large series of out-of-hospital cardiac arrest patients.

| | N (%) or Mean (95% CI:) |
|---|---|
| Gender | |
| Male | 1853 (59.4) |
| Female | 1268 (40.6) |
| Age | 67.4 (66.3, 68.6) |
| Witnessed | 1689 (54.4) |
| Primary Ventricular Fibrillation | 516 (16.9) |
| Bystander CPR | 857 (31.2) |
| ROSC | 695 (22.4) |
| EtCO$_2$ (All cases) | 18.7 (18.2, 19.3) |
| EtCO$_2$ (Survivor) | 27.6 (26.3, 29.0) |
| EtCO$_2$ (Non-survivor) | 16 (15.5, 16.5) |
| Automatic External Defibrillator | 596 (19.2) |

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**Table 1**—Demographic information 2006–2007 (n = 3,121)

| ROSC | Odds Ratio | *P*-value | 95% CI: |
|---|---|---|---|
| Age | 1.00 | 0.962 | 0.99, 1.00 |
| Male Gender | 0.58 | <0.001 | 0.41, 0.81 |
| Witnessed Arrest | 1.51 | 0.017 | 1.07, 2.12 |
| Bystander CPR | 0.97 | 0.885 | 0.68, 1.39 |
| Primary Ventricular Fibrillation | 1.48 | 0.053 | 1.00, 2.21 |
| EtCO$_2$ >10 | 4.79 | <0.001 | 3.10, 4.42 |
| EtCO$_2$ drop less than 25% | 2.82 | <0.001 | 2.01, 3.97 |
| Automatic External Defibrillator | 0.92 | 0.693 | 0.62, 1.38 |

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**Table 2**—Multivariate logistic regression analysis of return of spontaneous circulation (ROSC)

## Methods

This was a retrospective study of all adult (>18 years of age), non-traumatic, out-of-hospital cardiac arrest patients in the city of Los Angeles, California (USA), from 01 January 2006 through 31 December 2007. Only patients on whom resuscitative efforts were initiated by paramedics were included. Emergency medical services in Los Angeles are provided by the Los Angeles Fire Department, a tiered EMS system staffed by Emergency Medical Technician-Defibrillation firefighters and firefighter paramedics.[9]

Paramedics intubate adult cardiac arrest patients as per advanced cardiac life support guidelines. All patients are orally intubated after the provision of two minutes of CPR and one defibrillation (if indicated). Digital, waveform capnography is captured via the endotracheal tube as soon as the tube is secured, using the LifePak 12 (Medtronics Corp, Redmond, WA). Carbon dioxide is measured using a sidestream configuration that is located within the cardiac monitor (Oridion, Inc, Needham, MA).

All out-of-hospital cardiac arrest cases were reviewed after hand-written records were captured in an electronic database (Microsoft Access, Microsoft, Inc., Redmond, Washington). All patient identifiers were removed. The primary outcome variable was ROSC from the primary cardiac arrest. Approval to conduct this study was granted by the Institutional Review Board of the University of Southern California.

For the purposes of this study, the following variables were collected for analysis: gender, witnessed vs. unwitnessed arrest, initial EtCO$_2$, final EtCO$_2$, documented primary ventricular fibrillation (VF) (or pulseless ventricular tachycardia), use of automatic external defibrillator and presence or absence of bystander CPR.

Statistical analysis was performed using STATA 10.0 software (College Station, TX). Initial EtCO$_2$ ≤10 was chosen *a priori*; and relative fall >25% from the initial value to final value upon termination of resuscitation or arrival at the emergency department was chosen *a priori* as independent variables. There was no specific recruitment goal, since this study is establishing the frequency of ETCO$_2$ values <10 and percent change during the course of prehospital care. The records were reviewed and EtCO$_2$ analyzed at initial and final values, and therefore, the specific rate of change was not analyzed. Multivariate logistic regression analysis was performed in order to determine if EtCO$_2$ is a significant predictor of return of spontaneous circulation. Analysis of variance (ANOVA) was used for comparison of means. The Hosmer-Lemeshow statistic was determined to estimate the goodness of fit for the multivariate model.

## Results

There were 3,121 patients included in the study, of which, 1,689 (54%) were witnessed arrests and 516 (17%) were primary VF. The mean initial EtCO$_2$ was 18.7 (95%CI = 18.2–19.3) for all patients. Return of spontaneous circulation was achieved in 695 (22.4%) of patients, for whom the mean initial EtCO$_2$ was 27.6 (95%CI = 26.3–29.0). For those patients who failed to achieve ROSC, the mean initial EtCO$_2$ was 16.0 (95%CI = 15.5–16.5). (Table 1).

The following variables were significantly associated with ROSC: witnessed arrest (OR = 1.51; 95%CI = 1.07–2.12); initial EtCO$_2$ >10 (OR = 4.79; 95%CI = 3.10–4.42); and EtCO$_2$ falling <25% of baseline (OR = 2.82; 95%CI = 2.01–3.97) (Table 2).

The combination of male gender, lack of bystander CPR, unwitnessed collapse, non-vfib arrest, initial EtCO$_2$ ≤10

and $EtCO_2$ falling >25% was 97% predictive of failure to achieve ROSC.

## Discussion

There is evidence that suggests that $EtCO_2$ can be used to determine when resuscitative efforts should be discontinued.[10–12] Our study was one of the largest to-date that compared $EtCO_2$ data with other known variables that have been associated with survival of out-of-hospital cardiac arrest victims studies, such as age, gender, witness present, bystander CPR, and primary VF.

A model was used to predict survival using dichotomous ($CO_2$ >10 or ≤ 10) $EtCO_2$ values. The cut-off value of 10 mm Hg was chosen because previous clinical studies reported a correlation with ROSC above and below these values.[13–15] In this study cohort, individuals with an $EtCO_2$ >10mmHg were four times more likely to survive relative to those patients with $EtCO_2$ <10mmHg. These factors had the highest correlation with ROSC relative to the other variables also analyzed in this study: age, gender, witnessed, bystander CPR, primary VF, or automatic external defibrillator (AED). This is consistent with the findings of Cantineu *et al.*, who reported that a maximal $EtCO_2$ >10 during the first 20 minutes of resuscitation after intubation had a sensitivity of 100% in predicting ROSC.[4] Given this previous report, and the data from this study, it appears that an initial $EtCO_2$ of ≤10 mm Hg is the strongest predictor of mortality in the setting of cardiac arrest. Even so, it was not possible to create a model that was 100% predictive of mortality in the current population.

Death, as represented by lack of ROSC, was predicted in 97% of patients if they were male, no bystander was present to perform CPR, the collapse was unwitnessed, and the patient was not in primary VF, if $EtCO_2$ was ≤10 or if $EtCO_2$ fell >25% from baseline, and if no AED was used. However, since 3% of patients who had all of these variables present achieved ROSC, this data alone does not justify terminating resuscitative efforts.

The value of the change in $EtCO_2$ during resuscitation also was examined. Although the number of subjects was smaller, there was a significant difference between survivors and non-survivors, even when correcting for the initial $EtCO_2$ value. Patients who survived demonstrated the smallest decreases in $EtCO_2$ during their resuscitative events when compared to those who did not survive. It has been suggested that this lack of change in ETCO2 for eventual survivors may be an earlier indicator of returned cardiac function, preceding a palpable pulse.[16]

### Limitations

As our study was retrospective, it suffers from the same limitations as any retrospective study, including inaccuracy of data. In addition, hand-written data records were used, since electronic downloads were not available at the time. Not all patients had $EtCO_2$ values recorded. Finally, ROSC was used as the primary outcome variable, which is only a surrogate marker of survival. Final hospital outcome data on patients who achieved ROSC in the field are not available.

## Conclusions

An initial $EtCO_2$ >10 is associated with an almost five-fold higher rate of ROSC in out-of-hospital cardiac arrest. In addition, a decrease in the $EtCO_2$ during resuscitative events of >25% was associated with a significant increase in mortality, independent of other variables known to effect outcome. $EtCO_2$ values should be included as important variables in protocols to terminate or continue resuscitation in the prehospital setting.

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