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Brief Report

The sixth vital sign: prehospital end-tidal carbon dioxide predicts in-hospital mortality and metabolic disturbances

Christopher L. Hunter, MD, PhD [a,b,*], Salvatore Silvestri, MD [a,b], George Ralls, MD [a,b], Steven Bright, MD [b], Linda Papa, MD, MSc [a]

[a] Department of Emergency Medicine, Orlando Regional Medical Center, Orlando, FL, USA
[b] University of Central Florida College of Medicine, Orlando, FL, USA

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ABSTRACT

Objective: To determine the ability of prehospital end-tidal carbon dioxide ($ETCO_2$) to predict in-hospital mortality compared to conventional vital signs.
Methods: We conducted a retrospective cohort study among patients transported by emergency medical services during a 29-month period. Included patients had $ETCO_2$ recorded in addition to initial vital signs. The main outcome was death at any point during hospitalization. Secondary outcomes included laboratory results and admitting diagnosis.
Results: Of 1328 records reviewed, hospital discharge data, $ETCO_2$, and all 6 prehospital vital signs were available in 1088 patients. Low $ETCO_2$ levels were the strongest predictor of mortality in the overall group (area under the receiver operating characteristic curve (AUC of 0.76, 95% confidence interval [CI] 0.66-0.85), as well as subgroup analysis excluding prehospital cardiac arrest (AUC of 0.77, 95% CI 0.67-0.87). The sensitivity of abnormal $ETCO_2$ for predicting mortality was 93% (95% CI 79%-98%), the specificity was 44% (95% CI 41%-48%), and the negative predictive value was 99% (95% CI 92%-100%). There were significant associations between $ETCO_2$ and serum bicarbonate levels ($r = 0.429$, $P < .001$), anion gap ($r = -0.216$, $P < .001$), and lactate ($r = -0.376$, $P < .001$).
Conclusion: Of all prehospital vital signs, $ETCO_2$ was the most predictive and consistent for mortality, which may be related to an association with metabolic acidosis.

1. Introduction

Vital signs are an integral part of initial patient assessment, and abnormal values are believed to predict poor patient outcomes. Well-established vital signs include temperature, pulse, blood pressure, respirations and pulse oximetry. Exhaled end-tidal carbon dioxide ($ETCO_2$) can be measured non-invasively by capnography and may provide further information regarding physiologic function.

$ETCO_2$ is a continuous variable that is determined by basal metabolic rate, cardiac output, and ventilation [1]. Thus, abnormal levels may reflect derangement in perfusion, metabolism or gas exchange. It has multiple applications for monitoring of sedated patients [2], evaluation of proper endotracheal tube placement [3], and confirming return of spontaneous circulation during cardiopulmonary arrest [4]. Recent studies have suggested low $ETCO_2$ levels are associated with disease severity and mortality in adult patients with shock [5], sepsis [6,7], and metabolic disturbances [8], as well as pediatric patients with diabetic ketoacidosis [9] and dehydration [10]. Additionally, low $ETCO_2$ levels are associated with lactate levels [11], odds of operative intervention [12], and mortality [13] in trauma patients.

The purpose of this study is to investigate the clinical value of prehospital $ETCO_2$ measurement as an outcome predictor compared to conventional vital signs in an undifferentiated sample of patients. We hypothesize that abnormal $ETCO_2$ levels will predict mortality and metabolic disturbances, acting as an additional vital sign that may improve prehospital risk stratification.

2. Methods

2.1. Design and setting

We conducted a retrospective cohort study among patients transported by a single emergency medical services (EMS) agency to a single hospital during a two and a half year period from January 2009 through July 2011 in Orange County, FL. The institutional review board at the participating hospital approved the study protocol.

* Corresponding author. Orange County EMS, Orlando, FL 32806, USA. Tel.: + 1 407 836 6513; fax: +1 407 836 7625.
E-mail address: christopher.hunter@ocfl.net (C.L. Hunter).

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Table 1
Demographics

	Survivors n = 1048	Non-survivors n = 40	Total n = 1088	*P*
Age	53 (SD 19) [range 16-97]	64 (SD 21) [range 19-91]	54 (SD 19) [range 16-97]	.001
Gender (% male)	577 (55%)	21 (53%)	598 (55%)	.749
Race				.408
Asian	5 (1%)	0 (0)	5 (1%)	
Black	236 (23%)	7 (18%)	243 (22%)	
Hispanic	212 (20%)	6 (15%)	218 (20%)	
White	580 (55%)	25 (63%)	605 (56%)	
Other	15 (1%)	2 (5%)	26 (2%)	
Admitted to hospital	736 (70%)	40 (100%)	776 (71%)	<.001
Admitted to ICU	93 (9%)	21 (53%)	114 (11%)	<.001
Diagnostic category				.045
Abdominal/GI	120 (12%)	2 (5%)	122 (11%)	
Altered mental status	70 (7%)	0 (0)	70 (6%)	
Cardiac	252 (24%)	12 (30%)	264 (24%)	
Respiratory	106 (10%)	8 (20%)	114 (11%)	
Infectious/sepsis	78 (7%)	7 (18%)	85 (8%)	
Neurological	126 (12%)	4 (10%)	130 (12%)	
Metabolic/endocrine	46 (4%)	0 (0)	46 (4%)	
Trauma	105 (10%)	3 (8%)	108 (10%)	
Psychiatric	27 (3%)	0 (0)	27 (3%)	
Alcohol/drugs	45 (4%)	0 (0)	45 (4%)	
Other	73 (7%)	4 (10%)	77 (7%)	

We evaluated the records of all adult patients (≥ 18 years) who had prehospital $ETCO_2$ recorded and were transported to Orlando Regional Medical Center. During the study period, the standard practice for the participating EMS agency was to record $ETCO_2$ level as part of the initial set of vital signs in patients requiring advanced life support. Exclusion criteria included patient refusal to consent to standard therapy and interventions, pediatric patients (<18 years old), and patients without recorded prehospital $ETCO_2$. Orange County, Florida is an urban/suburban region with a population of approximately one million individuals. Orlando Regional Medical Center is a Level One trauma center with an emergency department (ED) volume of approximately 70,000 visits per year.

2.2. Data collection

Initial out-of-hospital vital signs documented by first arriving EMS personnel including respiratory rate (RR), systolic blood pressure (SBP), diastolic blood pressure (DBP), pulse (P), oxygen saturation (Spo_2), and $ETCO_2$ were obtained utilizing LIFEPAK 12 multi-parameter defibrillator/monitors. Prehospital measurement of $ETCO_2$ is a standard practice in Orange County and is performed by paramedics following protocols. $ETCO_2$ was measured via micro-stream capnography using LIFEPAK 12 devices (PhysioControl, Redmond, WA). Microstream capnography is an $ETCO_2$ sampling method using molecular correlation spectroscopy applicable to both intubated and non-intubated patients. $ETCO_2$ was recorded when capnographic wave peaks were at a constant end-tidal for 3 to 5 respirations as directed by protocol.

Patient age, gender, race, $ETCO_2$, RR, SBP, DBP, P, Spo_2, calculation of shock index (SI = P/SBP) and call type (trauma versus medical) were obtained from prehospital run reports. Patient mortality, admission to hospital or intensive care unit (ICU), initial ED vital signs, pertinent past medical history, principle and admitting diagnoses, as well as serum bicarbonate (HCO3), lactate, and calculated anion gap (when available) were obtained from the hospital chart. Records were linked by manual archiving of EMS and hospital data.

The primary outcome was death at any point during hospitalization. We also measured patient disposition described as discharge, hospital admission, or ICU admission, International Classes of Disease, ninth edition (ICD-9) codes, and the relationship between $ETCO_2$ and HCO3, anion gap, and lactate levels.

2.3. Analysis

Data were described using means and proportions with 95% confidence intervals (CI). Data were assessed for variance and distribution and comparisons between mortality and survival were performed using Fisher exact test and independent-samples *t* tests with pooled or separate variance as appropriate. Receiver operating characteristic (ROC) curves were constructed to assess the performance of $ETCO_2$, traditional vital signs, and SI for predicting mortality. The correlation between levels of $ETCO_2$ and HCO3, anion gap, and lactate were conducted using Pearson's correlation. Significance was set at .05. Data were analyzed using STATA (StataCorp, College Station, TX).

Table 2
Prehospital vital signs

	Survivors n = 1048 (95% CI)	Non-Survivors n = 40 (95% CI)	Total n = 1088 (95% CI)	*P*
$ETCO_2$	34 (34-35)	25 (21-29)	34 (33-34)	<.001
Respiratory rate	24 (23-24)	23 (19-27)	24 (23-24)	.535
Systolic BP	141 (139-143)	94 (75-115)	139 (137-141)	<.001
Diastolic BP	85 (84-86)	58 (45-70)	84 (83-85)	<.001
Pulse	95 (94-97)	89 (76-102)	95 (94-97)	.120
Oxygen saturation	95 (95-96)	82 (75-89)	95 (94-95)	<.001
SI	0.70 (0.69-0.72)	0.60 (0.45-0.75)	0.70 (0.68-0.72)	.179