Utility of Initial Prehospital End-tidal Carbon Dioxide Measurements to Predict Poor Outcomes in Adult Asthmatic Patients

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Abstract

Study objective. To determine if an initial (before treatment) prehospital end-tidal carbon dioxide ($EtCO_2$) measurement in adult, non-chronic obstructive pulmonary disease (COPD), asthmatic patients predicts patient outcomes. **Methods.** This is a retrospective chart review of $EtCO_2$ assessment data in a convenience sample of adult, asthmatic patients transported via advanced life support (ALS) units to a large, urban, academic hospital. Initial $EtCO_2$ measurements were obtained routinely on all respiratory distress patients in the field, and emergency department physicians were unaware of the results. Data were analyzed using descriptive statistics, including percentages, means, and 95% confidence intervals (CI). **Results.** We reviewed data for prehospital initial $EtCO_2$ measurements on 299 unique asthma patients (repeat visits by same patient were not included). Mean (SD) age was 43.1 years (12.5) and 142 (47.5%) were male. The mean $EtCO_2$ measurement was 38.8 mmHg (SD ± 9.5; CI: 37.7–39.9; range: 14–82). Examination of initial $EtCO_2$ measurements by deciles revealed that extreme values, in the lowest (14–28 mmHg) and highest (50–82 mmHg) deciles, experienced more markers of poor outcome than less extreme measurements. Patients were thus dichotomized by extreme ($n = 59$) or nonextreme ($n = 240$) $EtCO_2$ measurements. More extreme patients were ultimately intubated (30.5 vs. 5.8%; $p < 0.001$; positive predictive value (ppv) = 30.5%), and/or admitted to the intensive care unit (ICU) (28.8 vs. 6.7%; $p < 0.001$; ppv = 28.8%), and/or died (5.1 vs. 0%; $p = 0.007$ [Fisher's exact test]; ppv = 5.1%), than nonextreme patients, respectively. **Conclusion.** Extreme (both low and high) prehospital initial $EtCO_2$ measurements may be associated with markers of poor patient outcomes. Future work will prospectively determine whether the addition of this information improves early recognition of severe asthma episodes beyond clinical assessment. **Key words:** emergency medicine, asthma, end-tidal carbon dioxide, $EtCO_2$

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Introduction

Asthma constitutes a major respiratory health issue in the United States with nearly 24 million Americans suffering from the disease.[1] It is not only responsible for greater than 3,000 deaths per year (mainly in a young population), but also accounts for millions of visits to emergency departments (ED) per year.[1–4] In addition to appropriate management of the asthmatic patient in acute respiratory distress, it is the accurate early ED prediction of the need for hospitalization that may facilitate early decision-making, identify patients who will require more intensive therapy in a monitored setting, and maximize ED throughput.[5,6]

In order to identify asthmatic patients who may have worsening and persistent respiratory symptoms or fatal short-term relapse, most ED clinicians typically rely on a variety of clinical data to risk-stratify patients (on the spectrum ranging from mild to severe exacerbations). In addition to a thorough history and physical examination, these clinical data may include vital signs (tachycardia, tachypnea), pulse oximeter readings, arterial blood gas (ABG) studies, and peak expiratory flow (PEF). Some parameters are subject to varied interpretation (such as degree of accessory muscle use or work of breathing), while others may be imperfectly and variably related to the severity of the exacerbation. For example, the peak flow measurement is often cited for use in patients with asthma exacerbations; however, it is an extremely effort-dependent tool for measuring pulmonary function. PEF exhibits more variability when pulmonary function is more impaired (the seriously ill asthmatic may not be able to provide the necessary effort) and it may sometimes underestimate the degree of impairment, therefore limiting its use and reliability in the acute setting.[7] ED clinicians therefore tend to use a combination of available parameters for decision-making.

End-tidal carbon dioxide ($EtCO_2$) measurement is one such parameter that has gained value in recent

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years due to the fact that it is a rapid, noninvasive, mostly effort-independent, objective measure of a patient's alveolar ventilation status.[5] There is now ample literature to highlight the benefits of $EtCO_2$ measurements to monitor the ventilation status of patients under anesthesia and those undergoing procedural sedation, in the intensive care unit (ICU), operating room, and ED setting.[1–8] $EtCO_2$ measurement is also being used increasingly in the prehospital setting for monitoring ventilation status in intubated patients.[8] Emergency medical service (EMS) providers usually initiate aggressive treatment measures in patients with acute exacerbations of asthma and it remains unclear if an initial pretreatment $EtCO_2$ measurement may add value for predicting the outcomes for such patients.

The goal of this study was to describe the distribution of initial prehospital $EtCO_2$ measurements in adult, non-chronic obstructive pulmonary diseases (COPD), asthmatics, in relation to patient outcomes. Early identification of "sick" and at-risk asthmatics that may require intensive care level support may lead to earlier, more aggressive treatment in the ED that may ultimately impact need for hospitalization, mechanical ventilation and its related complications, and related increased healthcare costs. We sought to determine if prehospital $EtCO_2$ monitoring is useful in predicting negative outcomes in those patients with an acute exacerbation of asthma.

METHODS

Study Design, Setting, and Population

This was a retrospective chart review of $EtCO_2$ assessment data in a convenience sample of adult asthmatic patients transported via advanced life support (ALS) units to a large, urban, academic hospital. The study was conducted over a period from October 2005 through January 2008. Initial $EtCO_2$ measurements were obtained routinely on all adult (18 years or older) patients with respiratory distress in the field. Reasons for EMS dispatch included chief complaints of asthma, respiratory distress, breathing problem, shortness of breath, or COPD.

The EMS (an affiliate of the University of Medicine and Dentistry of New Jersey [UMDNJ]) is among the largest, comprehensive prehospital care systems in the nation. The study site, The University Hospital (UH)-EMS, is a state affiliated service that incorporates advanced life support and basic life support units, rescue, 9-1-1 EMS/fire communications, special operations, air medical, critical care transport, tactical medicine, research, training, and education. The ALS division operates six mobile units and overall EMS responds to over 100,000 dispatch calls per year. The study was approved by the UMDNJ institutional review board.

$EtCO_2$ measurements were obtained from Physio Control Smart CapnoLine Plus with O_2 Delivery Adult/Intermediate #11996-000163. This unit uses a nasal cannula, and the device is a sidestream capnometer. These detectors were ideal in that the patient's carbon dioxide levels were recorded on their electrocardiogram test printouts. An initial, first-contact $EtCO_2$ reading was obtained and used for study. Prior to the study period, EMS personnel were trained during the EMS annual recurrencies by the UH-EMS training supervisor to ensure proper usage and consistency in collection. $EtCO_2$ measurements were documented on the ALS run sheets as well. However, medics were not given any specific coaching instructions for the patients. $EtCO_2$ is not entirely effort-independent. The "CO_2 gap" may be affected by multiple variables: primarily problems with pulmonary blood flow (shock) and problems with airflow (asthma). A "coached" breath (i.e., asking the patient to "take deep breaths") may minimize the CO_2 gap. The initial $EtCO_2$ measurements obtained in our study did not involve coached breaths. Though medics obtained training for the proper use of $EtCO_2$ monitor, they were not instructed to coach patients. $EtCO_2$ readings were obtained at patient baseline respiratory effort.

Study Protocol, Measurements, and Data Collection

Two research assistants (RN, SB) reviewed all ALS dispatch records during the study period and extracted eligible patient care reports (PCRs) that met study inclusion criteria listed above (call for respiratory distress, shortness of breath, asthma, etc.). PCRs from EMS dispatch calls with a chief complaint of respiratory distress were screened for inclusion. Patients were included in the study if they had a documented past medical history of asthma on the ALS run sheet and a final diagnosis of asthma on ED discharge, hospital admission, or hospital discharge. Applicable ALS records could not be located for the time period from March 1, 2006 through March 31, 2006 and for the individual days of July 27, 2006 and August 14, 2006.

All respiratory distress patients transported by ALS had the initial (first-contact) $EtCO_2$ measurement recorded before initiating prehospital treatment. Data collection included patient demographics, prior history of asthma, any co-morbid conditions, and EMS field recorded pulse oximeter and $EtCO_2$ readings. Corresponding in-hospital electronic medical records were then reviewed to determine the in-hospital diagnosis and primary outcome of final disposition (hospital admission [to floor or ICU], ED death, or discharge home). Secondary outcome measures included length of stay in the ED and placement of endotracheal tube for assisted mechanical ventilation. Patients were excluded from the study if they were transported by BLS only or transported to another facility, no electronic medical records were available for review,

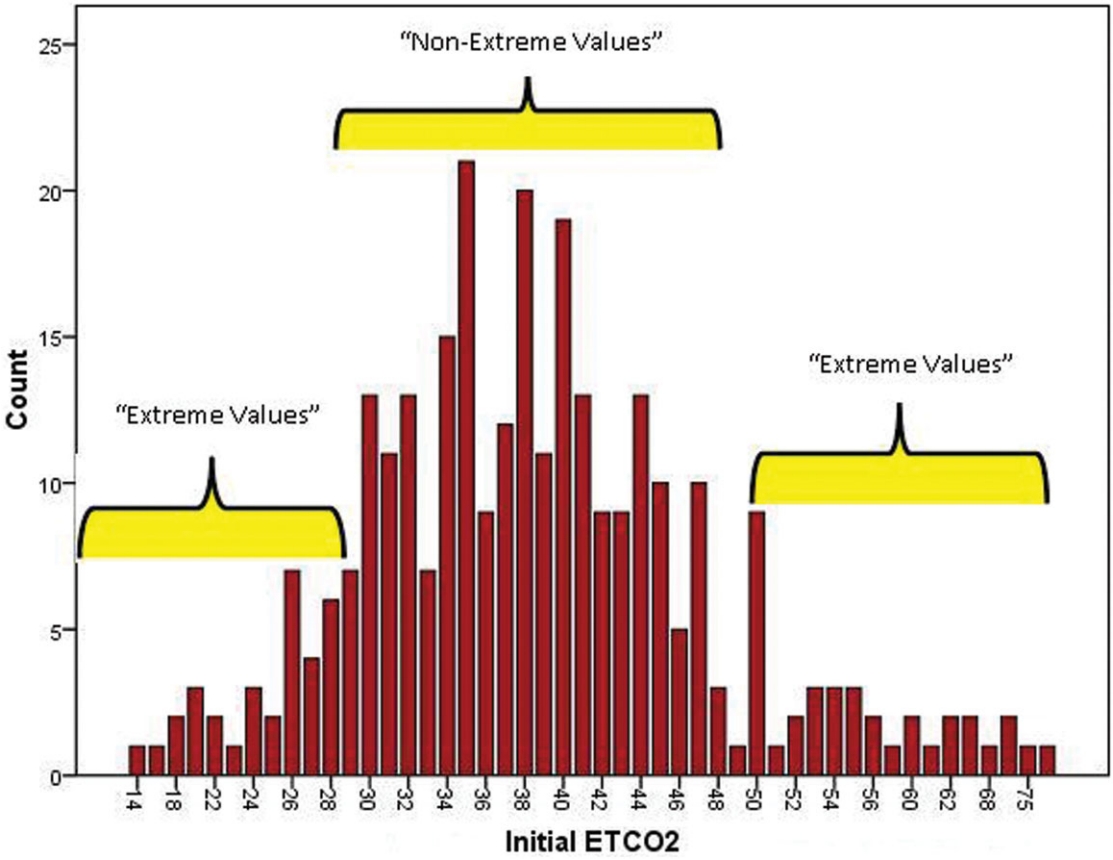

FIGURE 1. Patients dichotomized into Extreme vs. Non-Extreme Values.

patient age was less than 18 years, asthma was not listed as the final or discharge diagnosis, there was incomplete or missing PCR documentation, or there was no documented $EtCO_2$ value on the ALS care flow sheet. Further analysis was performed on only the subset of unique asthma patients (repeat visits by same patient were not included) with a final listed diagnosis of asthma and an $EtCO_2$ value recorded by EMS.

Data Analysis

Data were analyzed using descriptive statistics, including percentages, means, and 95% confidence intervals (CI). In addition, comparisons between patients with and without markers of poor outcome were performed using chi-square analyses and Fisher's exact tests, with an aim toward hypothesis generation for future prospective studies of the potential added value of initial $EtCO_2$ measurements to aid in the recognition of severe asthma.

RESULTS

More than 3,000 EMS eligible ALS charts were reviewed. Of these, 299 were unique asthma patients (repeat visits by same patient were not included). The mean age was 43 years (standard deviation [SD] 12); 47% (142/299) were male. The overall mean $EtCO_2$ measurement was 39 mmHg (SD $\pm$ 9.5; confidence interval [CI]: 38–40; range: 14–82).

Preliminary review of initial $EtCO_2$ measurements by deciles demonstrated that extreme values in the lowest (14–28 mmHg) and highest (50–82 mmHg) deciles experienced more markers of poor outcome than less extreme measurements. There was no a priori grouping. We defined "extreme values" as approximately the top 10% and bottom 10% of $EtCO_2$ measurements in our data set. Therefore, patients were dichotomized by extreme ($n = 59$) or nonextreme ($n = 240$) $EtCO_2$ measurements (Figure 1). More males were in the extreme group than in the nonextreme group (64 vs. 43%, respectively; $p = 0.004$), and there was no difference in the mean age (44 vs. 43 years; $p = 0.520$). More extreme patients were ultimately intubated (30 vs. 6%; $p < 0.001$; positive predictive value [ppv] = 30.5%), and/or admitted to the ICU (29 vs. 7%; $p < 0.001$; ppv = 28.8%), and/or died (5 vs. 0%; $p = 0.007$; ppv = 5.1% [Fisher's exact test]), than nonextreme patients, respectively. Patient characteristics for low vs. high extreme $EtCO_2$ values were age: 43 vs. 45 ($p = 0.584$); male: 19/32 vs. 19/27 ($p = 0.380$); intubated: 23/32 vs. 18/27 ($p = 0.665$); ICU admit: 8/32 vs. 9/27 ($p = 0.481$); died: 3/32 vs. 0/27 ($p = 0.243$) (Figure 2).

DISCUSSION

Our study utilized an initial $EtCO_2$ measurement obtained during an acute asthma exacerbation in the prehospital setting to analyze patient outcomes. The major findings of our study include that both extremes—low and high—of $EtCO_2$ values in the prehospital setting are correlated with poor outcomes in patients with acute asthma exacerbations.

Asthma accounts for a large percentage of ED visits and contributes to significant morbidity in the relatively young (usually otherwise healthy) population. However, ED clinicians continue to face the challenge of easily identifying those patients who will have potential negative outcomes in a consistent and objective manner. Clinical criteria, objective data, or clinical asthma scores in either the prehospital setting or the ED setting may not be accurate at predicting similar morbidities or mortality.[9,10] Treatment and disposition in asthmatics is therefore often based on the clinical acumen of the treating clinician with limited support from objective clinical data.

$EtCO_2$ and continuous $EtCO_2$ monitoring or capnography is being increasingly used as an adjunct to monitor the respiratory status of intubated patients under anesthesia and those under moderate to heavy procedural sedation.[8] Recently, $EtCO_2$ monitoring of respiratory status in the prehospital setting has been shown to be effective when used to confirm endotracheal tube placement and the quality of cardio-pulmonary resuscitation/compressions and to monitor the ventilatory status of intubated patients in the field.[8–12] $EtCO_2$ readings have demonstrated reliability when using an appropriately sized nasal cannula, and accuracy when taken in the prehospital setting.[13,14,17] The $EtCO_2$ values also show good concordance with CO_2 values obtained via arterial blood gas analysis.[13,14,18] Low $EtCO_2$ values have been shown to be predictive of poor outcome in major trauma (<24 mmHg) and in cardiac arrest (<10 mmHg).[15–17] A study in the pediatric population concludes that $EtCO_2$ may have use in predicting whether an asthmatic child in the ED needs to be admitted. However, to our knowledge no studies examine the value of prehospital $EtCO_2$ measurement in predicting outcomes in adult asthmatic exacerbations.

The major significant finding of our study is that both extremes (high and low) of $EtCO_2$ values in the prehospital setting are predictors of poor outcomes in adult asthmatics. These extreme values were associated with significantly more mortality and morbidity in our patients as compared to those patients who had an $EtCO_2$ value recorded in the relatively "normal (29–49)" range (ICU admission, mechanical ventilation, and death). There were no patient deaths in the "normal" range. It is not surprising to note that a higher $EtCO_2$ likely implies worsening ventilation status and therefore the need for mechanical support. However, we were surprised to find that the extreme lower $EtCO_2$ values also had the same associated poor outcomes. We surmise that in the prehospital setting such low $EtCO_2$ values may reflect an increased patient effort to breathe during an asthma exacerbation of significant severity as well. Since the ED setting did not have the capability of ongoing capnography during the study, we were unable to assess if the patients with low initial prehospital $EtCO_2$ continued with the same trend or showed a rise in $EtCO_2$ values before intubation due to fatigue. However, it is important to note that all three asthmatic deaths were in the extreme low $EtCO_2$ group. Further, larger prospective studies are needed to identify the utility of $EtCO_2$ measurements in the prehospital setting on ultimate patient outcomes in adult asthma. Future studies will also need to assess the particular significance of the extreme low $EtCO_2$ values in predicting asthma severity and negative outcomes.

LIMITATIONS

This was a single center retrospective analysis of records. We were unable to access medical records or analyze data on patients transported to facilities other than the study site. We obtained isolated $EtCO_2$ readings; trends in $EtCO_2$ change (or capnography) were not systematically recorded and may have been clinically significant. All consecutive eligible respiratory distress patients may not have had an $EtCO_2$ measurement for multiple reasons: short estimated arrival times, out-of-stock nasal cannula, difficulty locating $EtCO_2$ measurement on chart, and poor legibility. Though each encounter was cross-checked for final diagnosis accuracy with in-hospital electronic medical records, it is feasible that the patient was listed in medical records as well as by EMS as having a diagnosis of asthma while in fact suffered from COPD. Our findings were derived from a relatively small sample. Finally, we did not evaluate the response or change in $EtCO_2$ with appropriate therapy over time.

CONCLUSION

The results of this study suggest that extreme (both low and high) prehospital initial $EtCO_2$ measurements may be associated with markers of poor patient outcomes. Future work will prospectively determine whether the addition of this information improves early recognition of severe asthma episodes beyond clinical assessment and if capnography may serve as a useful adjunct in determining the severity of asthma and patient disposition.

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