Prehospital end-tidal carbon dioxide differentiates between cardiac and obstructive causes of dyspnoea

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ABSTRACT

Background Differentiating between cardiac and obstructive causes for dyspnoea is essential for proper management, but is difficult in the prehospital setting.

Objective To assess if prehospital levels of end-tidal carbon dioxide (ETCO2) differed in obstructive compared to cardiac causes of dyspnoea, and could suggest one diagnosis over the other.

Methods We conducted a retrospective cohort study among patients transported by emergency medical services during a 29-month period who were diagnosed with either obstructive pulmonary disease or congestive heart failure (CHF) by ICD-9 codes. Initial prehospital vital signs, including ETCO2, were recorded. Records were linked by manual archiving of emergency medical services and hospital data.

Results There were 106 patients with a diagnosis of obstructive or cardiac causes of dyspnoea that had prehospital ETCO2 levels measured during the study period. ETCO2 was significantly lower in patients diagnosed with CHF (31 mm Hg 95% CI 27 to 35) versus obstructive pulmonary disease (39 mm Hg 95% CI 35 to 42; p<0.001). Lower ETCO2 levels predicted CHF, with an area under the Receiver Operating Characteristics Curve of 0.70 (95% CI 0.60 to 0.81). Using ETCO2 <40 mm Hg as a cut-off, the sensitivity for predicting heart failure was 93% (95% CI 88% to 98%), the specificity was 43% (95% CI 33% to 52%), the positive predictive value was 38% (95% CI 29% to 48%), and the negative predictive value was 94% (95% CI 89% to 99%).

Conclusions Lower levels of ETCO2 were associated with CHF, and may serve as an objective diagnostic adjunct to predict this cause of dyspnoea in the prehospital setting.

Key messages

What is already known on this subject
It is difficult for prehospital providers to determine between cardiac and obstructive pulmonary causes of dyspnoea. Evidence suggests that end-tidal carbon dioxide (ETCO2), which can be measured non-invasively, may be significantly lower in dyspneic patients suffering from congestive heart failure.

What this study adds
This study suggests that lower prehospital ETCO2 levels may predict a diagnosis of congestive heart failure upon hospital admission. This may provide an objective measure for field evaluation of patients with dyspnoea.

INTRODUCTION

Differentiating between cardiac and obstructive causes is an important aspect of patient assessment in the setting of dyspnoea. However, many signs and symptoms overlap, making the proper diagnosis difficult.[1] Diagnosis frequently depends on chest radiographs or serum N-terminal pro-brain natriuretic peptide (BNP) depending on the clinical setting.[1] Prehospital providers are unlikely to have such diagnostic tests available to them, so a fast, non-invasive mechanism to objectively differentiate between these two common causes for dyspnoea could provide essential information.

Exhaled end-tidal carbon dioxide (ETCO2), a continuous variable that is determined by basal metabolic rate, cardiac output, and ventilation, can be measured non-invasively by capnography and may provide valuable information assessing acute dyspnoea.[2] Obstructive pulmonary disease (COPD/asthma) is characterised in part by hypoventilation, retention of carbon dioxide and high PaCO2, while pulmonary oedema caused by congestive heart failure (CHF) is characterised by, in part, by poor alveolar oxygen exchange and increased ventilation.[1] In a small prospective study, Brown *et al*[3] demonstrated that ETCO2 levels were significantly lower in emergency department patients with CHF compared to those with obstructive pulmonary disease. Additionally, using an algorithm including ETCO2 levels in addition to serum BNP has been shown to improve appropriate diagnosis by physicians in the prehospital setting.[4]

The purpose of this study is to investigate the relative clinical value of prehospital ETCO2 and oxygen saturation (SPO2) measurements as mechanisms to differentiate between obstructive pulmonary and cardiac causes of dyspnoea. We hypothesise that lower prehospital ETCO2 levels may predict CHF versus obstructive pulmonary disease.

METHODS

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, Florida. The institutional review board at the participating hospital approved the study protocol.

We evaluated the records of all adult patients (≥18 years) who had prehospital ETCO2 recorded who were transported to Orlando Regional

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Medical Center (ORMC), and were subsequently diagnosed with acute dyspnoea caused by obstructive pulmonary or cardiac disease. During the study period, the standard practice for the participating EMS agency was to record ETCO2 level as part of the initial set of vital signs in patients requiring ALS. Exclusion criteria included patient refusal to consent to standard therapy and interventions, paediatric patients (<18 years old), and patients without recorded prehospital ETCO2. Orange County, Florida is an urban/suburban region with a population of approximately one million individuals. ORMC is a Level One trauma centre with an ED volume of approximately 70 000 visits per year.

Data collection

Initial out-of-hospital vital signs documented by first-arriving EMS personnel including RR, systolic BP (SBP), diastolic BP (DBP), pulse (P), oxygen saturation (SPO2), and ETCO2 were obtained using LIFEPAK 12 multiparameter defibrillator/monitors. Prehospital measurement of ETCO2 is a standard practice in Orange County, and is performed by paramedics following protocols. ETCO2 was measured via microstream capnography using LIFEPAK 12 devices (PhysioControl, Redmond, Washington, USA). Microstream capnography is an ETCO2 sampling method using molecular correlation spectroscopy applicable to intubated and non-intubated patients. ETCO2 was recorded when capnographic wave peaks were at a constant end-tidal for 3–5 respirations as directed by protocol.

Patient age, gender, ETCO2, RR, SBP, DBP, P and SPO2 were obtained from prehospital run reports. Principle diagnosis of obstructive pulmonary disease, including chronic obstructive pulmonary disease (COPD) or asthma, and cardiac disease, including CHF or pulmonary oedema, were obtained from the hospital chart and defined by International Classes of Disease, ninth edition (ICD-9) codes. The ICD-9 code for the patient's *principle diagnosis* from the specific admission was used, so patients with a history of both types of disease were placed only in the group whose exacerbation caused the admission. ICD-9 codes used included 491 and 493 for obstructive disease, and ICD-9 428 for CHF. Mortality and admission to hospital or intensive care unit (ICU) were also obtained from the hospital chart. Records were linked by manual archiving of EMS and hospital data.

Analysis

Data were described using means and proportions with 95% CIs. Data were assessed for variance and distribution, and comparisons between CHF and obstructive pulmonary disease were performed using Fisher's Exact test, and independent sample t tests with pooled or separate variance, as appropriate. The accepted normal range of ETCO2 is 30–40 mm Hg, so for sensitivity, specificity, positive/negative predictive values, and likelihood ratios, data was analysed using an ETCO2 <40 mm Hg as a cut-off. Receiver Operating Characteristics curves (ROC curves) were constructed to assess the performance of ETCO2 and SPO2 for predicting CHF. As a statistical measure, the area under the ROC curve measures the accuracy of a test—an area of 1 or −1 represents a perfect test, an area of 0.50 represents a poor test. Significance was set at 0.05. Data were analysed using STATA (StataCorp, College Station, Texas, USA).

RESULTS

There were 106 patients with a diagnosis of asthma/COPD or CHF who had prehospital ETCO2 levels measured during the study period: 75 patients with a diagnosis of asthma/COPD and 31 with CHF. No patients were intubated prior to hospital arrival. The mean age was 59 years (SD20), 58 (55%) were women, 82 (77%) were admitted to the hospital, 5 (5%) were admitted to the ICU, and 1 (1%) died (see table 1). Patients with CHF were older (69 vs 56 years old, p=0.003), and more likely to be admitted to the hospital (68% vs 100%, p=0.002). Patients diagnosed with CHF also had higher RRs (31 vs 26 bpm, p=0.046) and DBP (98 vs 86 mm Hg, p=0.009) than those with COPD/asthma (see table 1). ETCO2 levels were significantly lower in patients with cardiac causes of dyspnoea. Mean levels of ETCO2 in patients with CHF were 31 mm Hg (95% CI 27 to 35 mm Hg) compared with 39 mm Hg (95% CI 35 to 42 mm Hg, p<0.001) for those diagnosed with COPD/asthma (see table 1). There was no significant difference in the mean SPO2 levels in each group; 93% (95% CI 92% to 95%) in COPD/asthma, and 93% (95% CI 90% to 96%, p=0.83) in CHF.

Using ETCO2 <40 mm Hg as a cut-off for hypoventilation (see figure 1), the sensitivity for predicting CHF was 93% (95% CI 88% to 98%), the specificity was 43% (95% CI 33% to 52%), the positive predictive value was 38% (95% CI 29% to 48%), and the negative predictive value was 94% (95% CI 89% to 99%). The positive Likelihood Ratio was 1.63 (95% CI 1.31 to 2.03), and the negative Likelihood Ratio was 0.15 (95% CI 0.04 to 0.60).

To evaluate the usefulness of non-invasive measures for oxygenation (SPO2) and ventilation (ETCO2) in the prehospital setting, ROC curves were constructed to determine the accuracy of ETCO2 and SPO2 in predicting CHF. The area under the ROC curve for predicting CHF was 0.70 (95% CI 0.60 to 0.81) for ETCO2 and 0.50 (95% CI 0.37 to 0.62) for SPO2 (see figure 2).

DISCUSSION

This study demonstrates that prehospital ETCO2 levels are lower in patients presenting with dyspnoea caused by heart failure, as compared with obstructive pulmonary disease, and that ETCO2 outperforms SPO2 at predicting CHF in this patient population. Prior reports have similarly found that ETCO2 is lower in patients with CHF versus those with obstructive pulmonary disease,[3] and have described using ETCO2 in conjunction with serum BNP to improve diagnostic accuracy in the prehospital setting.[4] ETCO2 has also been described as having prognostic value in CHF patients at rest[5] and undergoing exercise testing.[6] The use of capnography to measure ETCO2 may help differentiate obstructive versus pulmonary causes of dyspnoea in an environment where chest radiographs and serum BNP levels are not available.

ETCO2 is a continuous variable that is determined by basal metabolic rate, cardiac output and ventilation, and abnormal levels may reflect derangement in perfusion, metabolism or gas exchange. Capnography is used for monitoring ventilation of sedated patients,[7] evaluation of proper endotracheal tube placement,[8] and confirming return of spontaneous circulation during cardiopulmonary arrest.[9] Recent studies have suggested low ETCO2 levels are associated with disease severity and mortality in shock,[10] sepsis,[11] metabolic disturbances[12] and trauma.[13] Therefore, the lower ETCO2 levels found in CHF may be caused by a number of different factors, including increased ventilation or decreased perfusion. In the current study, patients with CHF also had an increased RR, suggesting that the decrease in ETCO2 may have been secondary to hyperventilation. The relationship between ETOC2 and CHF may be multifactorial, since the combination of factors that produce ETCO2

Table 1 Characteristics

	Total N=106	COPD/asthma N=75	CHF N=31	Significance p value
Age	59 (SD20)	56 (SD20)	69 (SD16)	0.003
Gender (% male)	48 (45)	35 (46)	13 (42)	0.675
Admitted to hospital (%)	82 (77)	52 (68)	31 (100)	0.002
Admitted to ICU (%)	5 (5)	3 (4)	2 (6)	0.628
Mortality (%)	1 (1)	1 (1)	0 (0)	0.999
Respiratory rate (95% CI)	28 (26 to 30)	26 (24 to 28)	31 (27 to 35)	0.046
Pulse (95% CI)	103 (98 to 108)	103 (98 to 108)	105 (95 to 115)	0.647
Systolic BP (95% CI)	149 (142 to 156)	146 (139 to 153)	158 (144 to 172)	0.105
Diastolic BP (95% CI)	89 (85 to 93)	86 (82 to 90)	98 (90 to 116)	0.009
ETCO2 (95% CI)	36 (34 to 38)	39 (35 to 42)	31 (27 to 35)	<0.001
SPO2 (95% CI)	94 (93 to 95)	93 (92 to 95)	93 (90 to 96)	0.83

CHF, congestive heart failure; COPD, chronic obstructive pulmonary disease; ICU, intensive care unit.

(metabolic rate, cardiac output, and ventilation) all might be deranged in the setting of heart failure.

A primary physiologic cause of dyspnoea in obstructive pulmonary disease is hypoventilation and resulting hypercapnia.[1] The relationship between ETCO2 and partial arterial carbon dioxide (PaCO2) in the setting of dyspnoea has not been completely elucidated. Prior studies have shown that ETCO2 may predict PaCO2 in patients with asthma,[14] and ED patients with acute dyspnoea.[15] However, the accuracy of ETCO2 to predict PaCO2 in acute dyspnoea has been questioned.[16] In the current study, we did not assess PaCO2 since we were evaluating prehospital ETCO2 prior to hospital arrival, and few of the enrolled patients had ABG analysis performed in the ED.

Since elevated ETCO2 likely reflects hypercapnia, we examined the relationship of lower levels with CHF. A prior report suggested ED patients with ETCO2>37 mm Hg are unlikely to have CHF.[3] Here, we found ETCO2 of less than 40 mm Hg had a high sensitivity, negative predictive value, and negative likelihood ratio, suggesting patients with dyspnoea and lower ETCO2 levels are more likely to have a cardiac aetiology. These findings demonstrate potential for prehospital providers to discriminate between causes of dyspnoea.

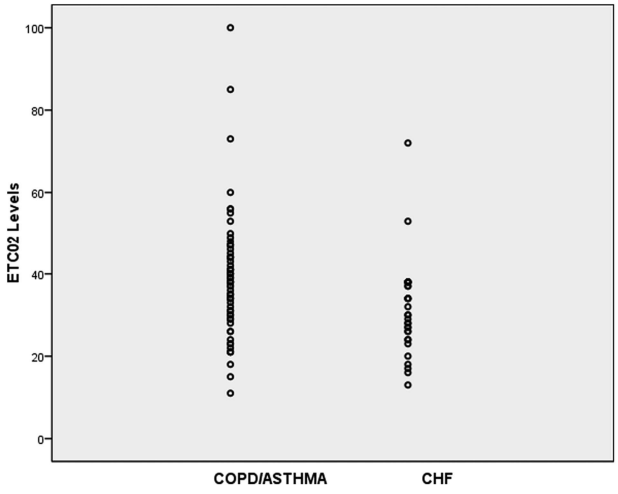

Figure 1 Scatter plot of ETCO2 distribution.

Using waveform capnography to assess patients with acute dyspnoea may provide information beyond the ETCO2. Krauss *et al*[17] demonstrated significant difference in the shape of the capnogram in obstructive disease versus those with normal and restrictive lung disease. It is possible that a combination of measurements including the ETCO2, alveolar plateau elevation angle, or take-off angle of the ascending phase may further elucidate obstructive pulmonary disease from other causes of acute dyspnoea.

Non-invasive methods for distinguishing disease processes play an important role in prehospital medicine. Prior reports have found novel applications for sonography in prehospital patients with acute dyspnoea, demonstrating high sensitivity for pleural effusions in patients with CHF.[18] In the future, combining sonography with capnography may provide a method for determining appropriate treatment in the field.

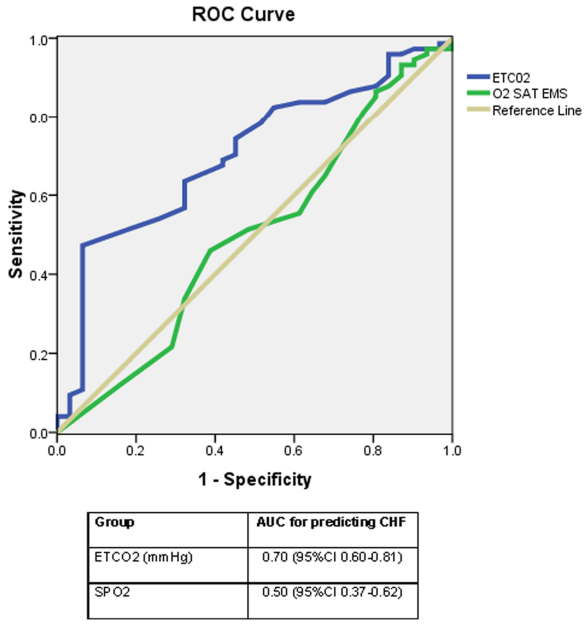

Figure 2 Receiver Operating Characteristics (ROC) curve for predicting congestive heart failure (CHF).

Limitations

There are several limitations to this study. This study was performed retrospectively and, thus, is subject to selection bias. The relatively small sample size may have contributed to the inability to define an ETCO2 cut-off with higher specificity and positive predictive value. This study was conducted using the data from a single EMS agency transported to a single hospital, and may not be applicable to all settings. Per protocol, ETCO2 was collected by paramedics only in patients requiring ALS care, so patients deemed to require only basic life support in the prehospital setting were excluded.

CONCLUSIONS

Lower levels of prehospital ETCO2 were associated with having CHF, and ETCO2 was better than SPO2 in distinguishing between obstructive pulmonary and cardiac disease. This suggests that ETCO2 could be a valuable tool for EMS providers assessing respiratory distress.

Contributors CLH, SS, GR and LP planned the study. CLH and SS obtained the data and performed chart review. CLH and LP performed data analysis. CLH, SS, GR and LP created the manuscript. CLH submitted the manuscript, and is responsible for the overall content as the guarantor.

Competing interests None.

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