ORIGINAL ARTICLE

End tidal carbon dioxide as a predictor of the arterial P_{CO_2} in the emergency department setting

C Yosefy, E Hay, Y Nasri, E Magen, L Reisin

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See end of article for authors' affiliations

Correspondence to: Dr C Yosefy, Department of Cardiology, Barzilai Medical Center, Ashkelon, 78306, Israel; yosefy@barzi.health.gov.il

Objectives: Patients arriving in the emergency department (ED) need rapid and reliable evaluation of their respiratory status. Mainstream end tidal carbon dioxide ($ETCO_2$) is one of the methods used for this purpose during general anaesthesia of intubated patients in the operating theatre. Sidestream $ETCO_2$ ($SSETCO_2$) might be a non-invasive, rapid, and reliable predictor of arterial P_{CO_2} in non-intubated patients in respiratory distress. The aim of this study was to verify whether $SSETCO_2$ can accurately predict the arterial P_{CO_2} and to detect variables that may affect this correlation.

Methods: A prospective semi-blind study. The participants were 73 patients (47 men, 26 women) referred to the ED for respiratory distress. Arterial blood gas pressures and $SSETCO_2$ measurements were performed and recorded for all patients. Other parameters recorded were: age; body temperature; respiratory rate; blood pressure; pulse rate; and medical diagnosis.

Results: A significant correlation was found between $SSETCO_2$ and arterial P_{CO_2} ($r = 0.792$). Compared with the correlation curve of the whole group, age under 50 years deflected the correlation curve to the left, while temperature above 37.6°C deflected it to the right. The rest of the parameters had no clear influence on the $SSETCO_2/P_{CO_2}$ correlation curve.

Conclusions: There is a good correlation between $SSETCO_2$ and arterial P_{CO_2} in the ED setting. Young age may increase the arterial $P_{CO_2}/SSETCO_2$ gradient while raised temperature may decrease this gradient. Further studies are needed to confirm these findings in the normal healthy population.

Patients in respiratory distress presenting in the emergency department (ED) require close assessment of their oxygenation, ventilation, and acid base balance. Arterial blood gases (ABG) examination provides accurate information, but an arterial blood analyser is not available in every ED and blood is usually sent to the laboratory. This whole procedure is time consuming and in some cases requires multiple arterial blood punctures to get one ABG sample. Alternative methods for immediate and continuous non-invasive monitoring include pulse oximetry and capnography (end tidal CO_2 ($ETCO_2$)).[1]

In the $ETCO_2$ capnography the gas to be analysed reaches the sample chamber in one of two ways[2]: a mainstream analyser that resides within the breathing circuit, usually between the end of the endotracheal tube and the Y connection. This method is usually used for infrared spectrometers. Because the sample chamber is part of the breathing circuit, the delay time is minimised and there are no problems with increased work of breathing or clogging by pulmonary secretions. However, the analyser is heavy, and may cause kinking or dislodgement of the endotracheal tube. The second method is using a sidestream analyser, in which the gas sample is aspirated from the breathing circuit through a small bore tube to a remote analyser. This method is mainly used for mass spectrometry and some infrared analysers. It adds little weight to the breathing circuit but the narrow lumen of the sampling tube is more likely to be clogged by pulmonary secretions and the delay time is much longer than the mainstream method. In addition, there may be some loss of the expired tidal volume caused by continuous sampling.

Both mainstream and sidestream $ETCO_2$ have been found to be closely correlated to arterial P_{CO_2}, especially in haemodynamically stable patients.[3 4] $ETCO_2$ monitoring is in daily use in general anaesthesia in adults,[5 6] in anaesthetised and non-intubated children,[7–9] and in non-intubated adult patients.[10 11] Sidestream $ETCO_2$ ($SSETCO_2$) was found to be quite a sensitive mean for identification of CO_2 pulmonary depression in children under conscious sedation, undergoing painful procedures, rather than the P_{O_2}, which falls only later.[9] $ETCO_2$ has also been used as a measure of pulmonary circulation, especially in circulatory shock, where it may have a prognostic value,[12–15] and in massive pulmonary embolism.[16] During endotracheal intubation, low values of $ETCO_2$ can indicate false location of the tube.[17 18]

$SSETCO_2$ is very suitable in the ED setting for patients in respiratory distress. It is immediate, non-invasive, and does not require cooperation of the patient. Sidestream capnography provides numerical values of the $ETCO_2$, $ETCO_2$ graph, and $ETCO_2$ trend. The last provides important information on circulatory status and ventilation.[15 16 19 20] The numerical value of the $SSETCO_2$ can be of great importance for the immediate evaluation of patients in severe respiratory distress, who are potentially CO_2 retainers.[21]

To verify whether $SSETCO_2$ can accurately predict the arterial P_{CO_2} and to detect variables that can affect this correlation, we conducted the following prospective semi-blind study in our ED.

METHODS

Patients who were referred to our ED because of respiratory distress and needed ABG were included in the study. The study was conducted during the morning and evening shifts, between January and June 2000. ABG was performed before administration of supplemental oxygen. Simultaneously, $SSETCO_2$ was measured by a sidestream capnometer (OHMEDA Model 4700 Oxycap monitor, a division of the BOC Group, Colorado, USA) using its standard nasal cannula

Abbreviations: ED, emergency department; $ETCO_2$, end tidal carbon dioxide; $SSETCO_2$, sidestream end tidal carbon dioxide; ABG, aterial blood gases

for $ETCO_2$ measurement. The highest reading was recorded because it best represents a full tidal volume. Immediately afterwards, oxygen was delivered according to the patient's state. The following initial parameters were recorded: age; body temperature; respiratory rate; blood pressure; pulse rate; and medical diagnosis. Exclusion criteria were: age under 18 years; any aetiology of shock and need for immediate resuscitation or intubation. The investigator measuring the ABG was totally blinded to the $SSETCO_2$ results. The study was approved by the local hospital ethics committee and all the patients signed a form of informed consent.

Statistical analysis

$SSETCO_2/P_{CO_2}$ correlation curve was plotted and tested using the single variable analysis method. The influence of the other variables was tested using the multivariant linear regression analysis method.

RESULTS

Seventy three patients were enrolled in the study, 47 men and 26 women. The mean (SD) age was 64.95 (18.97) years, range 18–95. $SSETCO_2$ ranged from 12–74 mm Hg. The medical diagnosis included 55 patients with pulmonary oedema (75.3%), 14 patients with exacerbation of chronic obstructive lung disease (19.2%), and four patients with exacerbation of bronchial asthma (5.5%). Table 1 lists the patients' characteristics.

The correlation between $SSETCO_2$ and P_{CO_2} was found to be linear (fig 1), with a correlation coefficient of 0.792. Age under 50 years caused the curve to shift to the left compared with the linear correlation curve of the whole group, and temperature above 37.6°C resulted in a shift to the right (figs 2 and 3). We did not find an influence of blood pressure, respiratory rate, or blood pH on the $SSETCO_2/CO_2$ curve, however, we did note a weak trend of a shift to the right with pH below 7.35 and diastolic blood pressure above 90 mm Hg. These trends were not statistically significant. We had the impression of a weak correlation (0.620) between the $ETCO_2$ and the P_{CO_2} with high respiratory rates (above 30/min).

DISCUSSION

Our results clearly show a good correlation between the arterial P_{CO_2} and the $SSETCO_2$. The mismatch between $ETCO_2$ and arterial P_{CO_2} reflects the discrepancy between the perfused and the ventilated alveoli. An increase in anatomical and physiological dead space and disturbances in pulmonary circulation, decreases the $ETCO_2$ and increases the $P_{CO_2}/ETCO_2$ gradient.[3 4 10] A gradient of 5–6 is considered normal in haemodynamically stable patients.[3 4 24] Pulmonary embolism and circulatory shock decrease the $ETCO_2$ level and increase the $P_{CO_2}/ETCO_2$ gradient.[3 15 16] Aging has been shown to increase the $P_{CO_2}/ETCO_2$ gradient, probably by increasing the anatomical dead space.[25] In another study of 314 patients, $ETCO_2$ decreased with age only in men.[26] In our younger group of patients (under 50 years), we recorded lower values of P_{CO_2}, and thus lower values of $ETCO_2$,

Table 1 Characteristics of study population

Parameter	Result
Patients (n)	73
Male, number (%)	47 (64.4)
Female, number (%)	26 (35.6)
Age (y)	64.95 (18.97)
SBP (mm Hg)	126 (4.2)
DBP (mm Hg)	78 (4.6)
Heart rate (beat/min)	76 (3.6)
Respiratory rate (per minute)	14 (2.1)
Temperature (°C)	37.2 (1.3)

Data in parentheses are SD unless stated otherwise. SBP, systolic blood pressure; DBP, diastolic blood pressure.

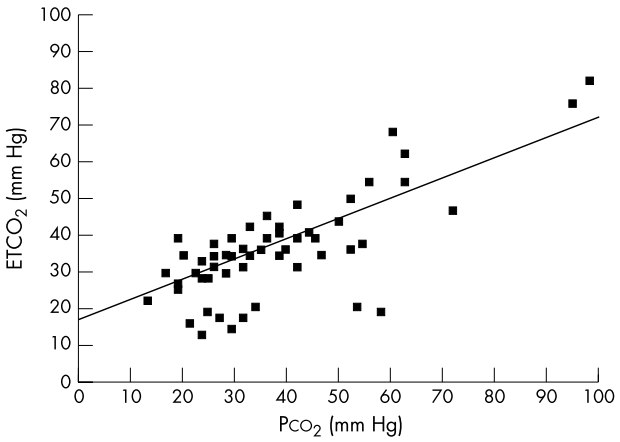

Figure 1 Linear correlation curve of $ETCO_2$ and P_{CO_2} of the whole group.

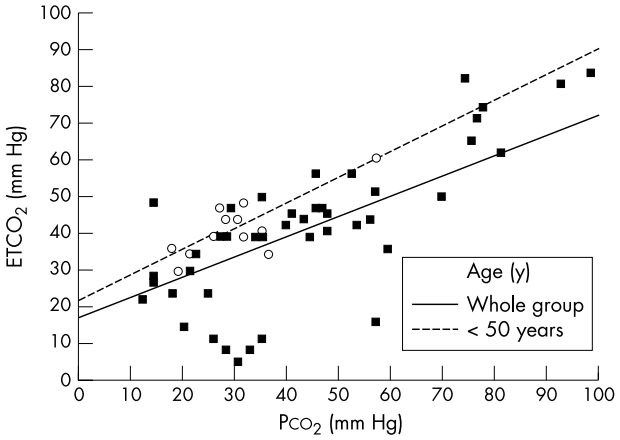

Figure 2 $ETCO_2/P_{CO_2}$ correlation curve for patients under age 50 compared with the whole group.

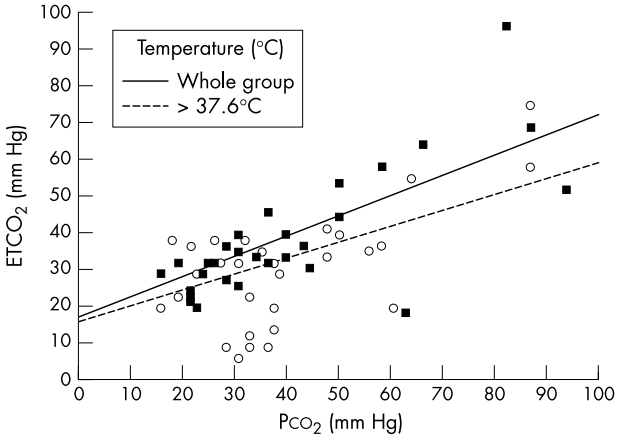

Figure 3 $ETCO_2/P_{CO_2}$ correlation curve for patients with temperature above 37.6°C compared with the whole group.

resulting in an increase in the $P_{CO_2}/ETCO_2$ gradient and a shift to the left of the curve. This may be explained by the higher frequency of asthma in the younger group than in the older one.

Increasing the temperature tends to decrease the $P_{CO_2}/ETCO_2$ gradient. This can be explained by the fact that the blood analyser is set to 37℃ and the solubility of CO_2 is increased with cooling.[4] This causes the curve to shift to the right, exactly as we have found in our study. The probable effect of increased diastolic blood pressure on the $ETCO_2/P_{CO_2}$ correlation curve in our study may be explained by the fact that most of the patients had pulmonary oedema, implying an increase in the dead space. In relation to the respiratory rate, From and Scamman state that the capnometer could not accurately predict changes in the $ETCO_2$ with high respiratory rates,[27] thus resulting in a low correlation coefficient. In our study we also had the impression that the correlation between the $SSETCO_2$ and the P_{CO_2} was weak with respiratory rate over 30/minute, but it did not reach statistical significance, probably because of the small number of patients.

We did not divide the patients into subgroups according to the level of arterial P_{CO_2} and the different pathogenesis. The subgroups would be too small to be compared and analysed statistically.

Our study has limitations. Firstly, the small number of patients. Secondly, the comparison of the influence of the different parameters on the curve of the whole group instead of a comparison with a nomogram in healthy controls. Therefore, further studies should be performed to determine a nomogram of healthy people and to examine the influence of the various parameters on this nomogram. Finally, the positioning of the sampling tube (mouth breathing) might have had some effect on the $ETCO_2$ estimate.

In summary, we found a good correlation between $SSETCO_2$ and arterial P_{CO_2} in the ED setting. Young age may increase the arterial $P_{CO_2}/SSETCO_2$ gradient while raised temperature may decrease this gradient. Further studies are needed to confirm these findings in the normal healthy population. We recommend the use of this non-invasive method in other EDs.

CONTRIBUTORS

Chaim Yosefy: principal inverstigator and writer. Emile Hay: investigator and co-writer. Yusuf Nasri: investigator and data collector. Eliyahu Magen: investigator and data collector. Leonardo Reisin: investigator, co-writer, and statistical analyser.

Authors' affiliations

C Yosefy, L Reisin, Department of Cardiology, Barzilai Medical Center, Ashkelon, Israel
E Hay, Department of Emergency Medicine, Barzilai Medical Center
Y Nasri, Department of Primary Medicine, Ben-Gurion University of the Negev, Israel
E Magen, WHO Collaborative Center for Prevention of Cardiovascular Diseases, Barzilai Medical Center

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