



Early View

Research letter

Transcutaneous CO₂ measurement is not a reliable alternative to arterial blood gas sampling in the acute medical setting

Victoria Mummery, Eleanor Rogers, Vijay Padmanaban, Dionne Matthew, Thomas Woodcock, Susannah Bloch

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Title: Transcutaneous CO2 measurement is not a reliable alternative to arterial blood gas sampling in the acute medical setting.

Victoria Mummery^{1, 2}, Eleanor Rogers¹, Vijay Padmanaban¹, Dionne Matthew², Thomas Woodcock², Susannah Bloch¹

1. Chest and Allergy Department, Imperial College Healthcare NHS Trust, London, UK
 2. NIHR CLAHRC Northwest London, Imperial College London, Chelsea and Westminster Hospital, London, UK
- Corresponding author: Susannah Bloch, Chest and Allergy department, St Mary's Hospital, Imperial College Healthcare NHS Trust, London W2 1NY. Susannah.bloch@doctors.org.uk; 07977147483

Key Words : Transcutaneous CO2, Arterial Blood Gas (ABG)

Introduction

Measurement of the partial pressure of carbon dioxide in the arterial blood (pCO₂) is essential in a variety of acute clinical settings and it is often necessary to monitor changes in pCO₂ over time rather than just a one-off measurement. The current gold standard of measuring pCO₂ is arterial blood gas (ABG) sampling, but the collection of arterial blood is invasive and associated with complications[1]. To avoid frequent arterial stabs, arterial lines are sometimes placed, but these result in the requirement for level 2 care and are associated with significant risks[2,3]. Transcutaneous measurement of CO₂ (TcCO₂) has been used in the field of sleep medicine and nocturnal monitoring of CO₂ using the transcutaneous method is widely recognised. The technique is non-invasive, low-risk, requires minimal training and is well tolerated[4,5]. However, it is not known if TcCO₂ can be used as a reliable measure of pCO₂ in the acute setting and the evidence to date supporting its use has been contradictory and from small studies of selected patient groups[6-8], who were often medically stable[9]. Patients being treated with Non-Invasive Ventilation (NIV) are often those who require the most frequent ABG monitoring and the recent UK NCEPOD (National Confidential Enquiry into Patient Outcome and Death) review of NIV care in the UK[10] highlights the need for careful and timely review of pCO₂ in these patients. An arterial line can help avoid distress to the patient, but increased pressure on resources and level 2 beds means that this is not always available and patients may therefore have to be subjected to repeated arterial stabs. Therefore we hypothesised that TcCO₂ would be reliable, easy to use and preferred by patients as a means of measuring CO₂ in the acute unselected medical setting.

Methods

Medical patients admitted to hospital acutely unwell who required at least one ABG test were eligible to participate. Patients were identified and approached consecutively from acute medical admissions patient lists. Ethical approval for the study was obtained (REC 17/LO/1137: IRAS 228887). Written consent, demographic and clinical data were collected. Patients completed a questionnaire about their experience of both techniques.

CO₂ measurement

The procedure for ABG sampling (both arterial stab and collection of blood from arterial lines) was carried out in the standard way either by the researcher or by the clinical team. ABGs were only taken at a time that was clinically indicated as determined by the clinical team. A Resmed SenTec monitor (SenTec AG, Ringstrasses 39, 4106 Therwil, Switzerland) was used to measure the TcCO₂. Details of the standard set up and calibration of the machine can be found at www.sentec.ch.tv. In

brief the technique involves the machine being used in its “spot check” mode and placement of an electrode sensor on the forehead of the patient. The sensor takes approximately 15 minutes to equilibrate before it will give a TcCO₂ reading. The arterial blood was sampled at the point at which the machine delivered the equilibrated reading.

Statistical Analysis

Bland Altman analysis calculating the actual difference vs the mean was used to compare paired readings of pCO₂ from arterial blood and the TcCO₂ (Graphpad Prism 6); 95% limits of agreement were calculated and a pre-determined value of 0.25 kPa as an acceptable difference ($\Delta = \pm 0.25$). The difference between the measurements was then correlated (Pearson’s correlation) with clinical parameters to determine any potentially influencing factors. The direction of change between two consecutive paired measurements within the same patient was compared between the two techniques of measuring CO₂ (ie where more than one paired sample was taken from the same patient at different time points the question was asked ‘did the CO₂ change in the same direction when measured by each technique’). Patient experience was analysed qualitatively.

Results

50 participants (23 male, median age 68years, range 17-90years) were recruited and consented to the study (72 screened, 5 patients did not require further ABG, 17 were unwilling or unable to consent). 45 patients completed the questionnaire; the 5 remaining were unable to partake in this element of the study due to their medical condition. Patients were admitted to hospital for a range of diagnoses – respiratory problems were most common (27/50,) followed by non-respiratory sepsis (7/50), then cardiovascular (5/50), the remaining 11 were admitted with other medical diagnosis (including neurological, diabetic and general medical issues). 74 paired samples (TcCO₂ and pCO₂) were collected; no one participant had more than 4 pairs of samples. The following clinical data were collected at the time of the CO₂ measurements (expressed as median (range)): Temperature 36.7°C (35.7-38.4), oxygen saturations 93% (83-100); Heart rate 88beats per minute (60-100), Mean Arterial blood pressure 86mmHg (53-109). The arterial blood gas measurements showed a median pCO₂ of 6.45kPa (3.4-13.4) and the TcCO₂ measurements 6.36kPa (3.1-12.6) n=74 for both.

Bland Altman analysis suggested that the bias of the TcCO₂ tended to be 0.16 (CI ± 1.54) kPa lower than the pCO₂ with 95% limits of agreement -1.67 to 1.35 kPa (Figure 1, panel A). The difference between the 2 measurements was compared to the mean arterial blood pressure, heart rate, temperature and oxygen saturations – none of these parameters were found to affect how much the TcCO₂ measurement differed from the pCO₂ (data not shown). 24 samples were collected consecutively; however in only 54% of cases (13/24) did the CO₂ change in the same direction when measured by the two techniques (Figure 1, panel B).

Patients overwhelmingly found the TcCO₂ measurement more tolerable than the arterial stab. No patients reported any pain and the only other comments were three patients out of 45 reported a feeling of “warmth on the skin” during the TcCO₂ measurement and one complained of slight heaviness where the probe was stuck to the skin. Arterial stabs were reported as painful and unpleasant (8 patients had arterial lines therefore did not comment on arterial stabs, 33 reported significant pain and the remaining 4 reported minor pain or a scratch.) Patients reported dreading arterial stabs where as 100% (45/45) said that they would have TcCO₂ measurements in the future.

Discussion

TcCO₂ is an attractive option for the measurement of CO₂, it is non-invasive, allows the patient to be managed in a low acuity area and requires little skill to carry out. Other studies have variably shown that TcCO₂ may[6,7] or may not[8] be a reliable alternative to the gold standard ABG pCO₂. This larger real world study, recruiting unselected acutely unwell patients with a range of diagnoses, demonstrates that TcCO₂ should not be used as an alternative to the ABG to monitor CO₂ levels. The limitations to the study include the fact only a Resmed SenTec monitor was tested and only the forehead position was used for placement of the sensor, other devices or sensors in other positions may show other results. However in this study the limits of agreement for the two techniques of measuring TcCO₂ were not only wide, but also lay significantly outside what may be an acceptable difference of ± 0.25 kPa. This is in line with previous work[11]. Furthermore the TcCO₂ could not be reliably used to suggest a trend or direction of change in CO₂ level. This is disappointing both for staff and patients as our qualitative patient analysis clearly demonstrated that TcCO₂ is a much more tolerable technique than ABG sampling. The study does not test whether or not either method of measuring pCO₂ can be used to predict clinical outcomes or direct clinical decisions, the study question was limited only to if the two methods of measuring CO₂ have comparable and clinically reliable results further research would be needed to answer this question. In conclusion, the results of this study suggest that TcCO₂ measured by this method should not be used in the acute clinical setting as an alternative to the pCO₂ measured by ABG sampling. Health economic pressures and patient experience considerations continue to call for more work to be done to find an alternative to the ABG.

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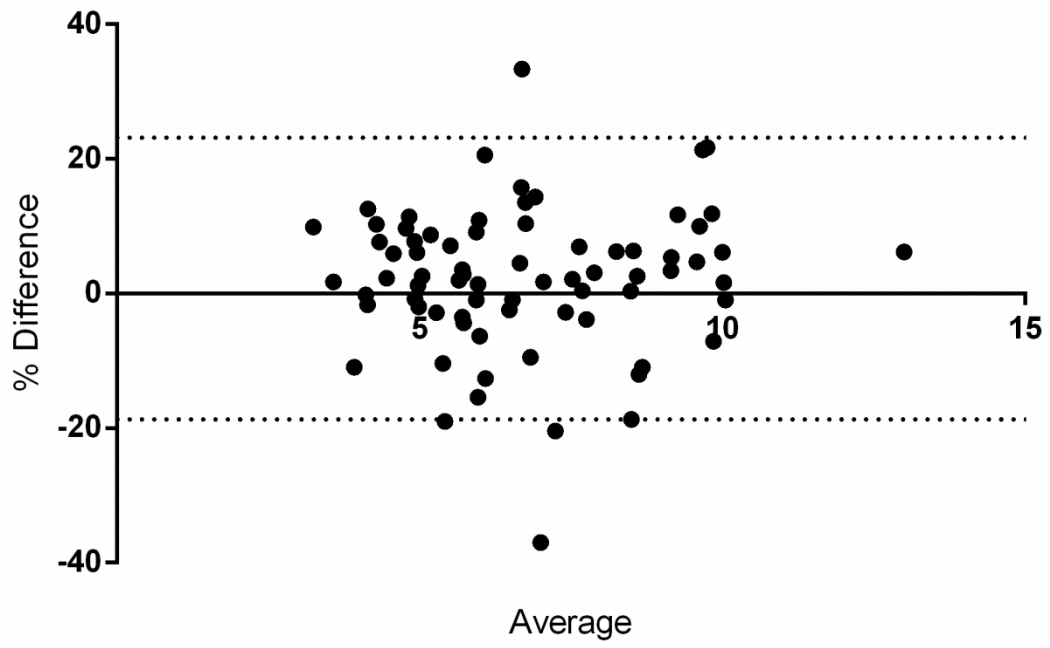
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Figure Legends

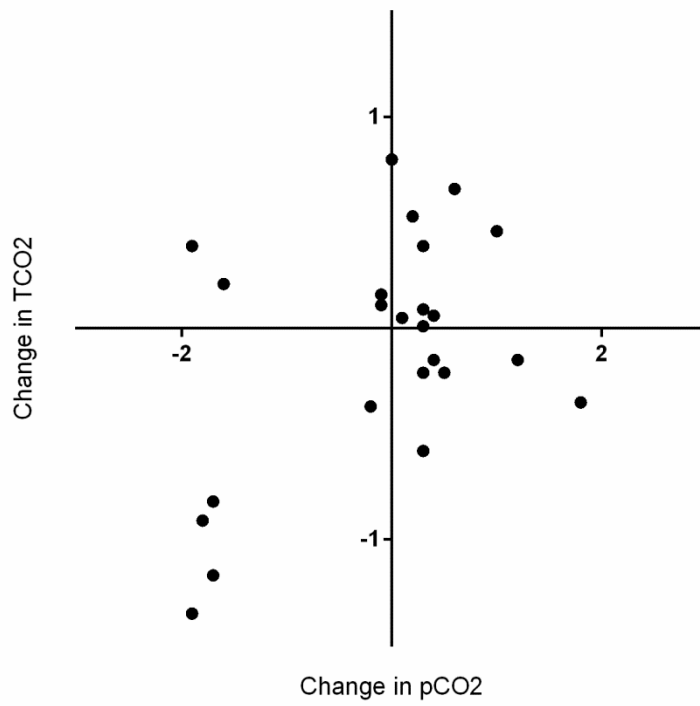
Figure 1:

Panel A: Bland-Altman plot to show the difference between CO₂ measured by Transcutaneous CO₂ monitoring (TcCO₂) and Arterial Blood Gas analysis (ABG) vs mean of the two measurements. N= 74, dotted lines = 95% limits of agreement (-1.67 , 1.35), dashed lines = clinically acceptable difference ± 0.25 kPa.

Panel B: Graph to show direction of change in CO₂ between two consecutive measurements in the same patient when measured by Transcutaneous CO₂ (TcCO₂) vs Arterial Blood Gas analysis (ABG). N=24



A



B