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Agreement between arterial and transcutaneous PCO_2 in patients undergoing non-invasive ventilation

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Summary
Aim: Transcutaneous carbon dioxide ($PtCO_2$) monitoring offers a potentially non-invasive and continuous means to determine the arterial carbon dioxide tension ($PaCO_2$). ED studies of agreement between $PtCO_2$ and $PaCO_2$ have had conflicting findings and have not been targeted to subgroups with severe ventilatory disturbance such as those requiring non-invasive ventilation [NIV]. Our aim is to determine agreement between $PtCO_2$ and $PaCO_2$ for patients undergoing NIV for respiratory failure.
Methods: This prospective observational study included a convenience sample of patients undergoing NIV for respiratory failure who required arterial blood gas analysis as part of their care. Data collected included patient demographics, indication for NIV, diagnosis, vital signs, and pH, $PaCO_2$ and $PtCO_2$. The outcome of interest was agreement between $PaCO_2$ and $PtCO_2$. Analysis was made using descriptive statistics, Bland-Altman techniques, Mann–Whitney *U* test and Fisher/Chi square tests.
Results: 46 comparisons were analysed. Median age was 69 [IQR 65–79], 67% male; median $PaCO_2$ 60 mmHg [IQR 46–70] and median pH 7.35 [IQR 7.30–7.38]. Average difference between $PaCO_2$ and $PtCO_2$ was 6.1 mmHg with 95% limits of agreement −10.1–22.3 mmHg. Thirty seven comparisons [80%] were within 10 mmHg [95% CI 66–90%]. Difference >10 mmHg was associated with increasing $PaCO_2$ [$p = 0.001$; median difference 19.6 mmHg, 95% CI 9.2–30.4 mmHg]. All cases with difference >10 mmHg had $PaCO_2 > 60$ mmHg.
Conclusion: In patients undergoing NIV, agreement between $PaCO_2$ and $PtCO_2$ was sub-optimal, with unacceptably wide 95% limits of agreement. $PtCO_2$ cannot be recommended as a substitute for $PaCO_2$ testing in this group.

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Introduction

Transcutaneous carbon dioxide ($PtCO_2$) monitoring offers a potentially non-invasive and continuous means to determine the arterial carbon dioxide tension ($PaCO_2$). A number of studies have reported good agreement between $PtCO_2$ and $PaCO_2$ values in surgical,[1,2] paediatric critical care[3] and cardiopulmonary exercise testing[4] settings. ED studies have had conflicting findings[5–7] and have not been targeted to subgroups with severe ventilatory disturbance such as those requiring non-invasive ventilation [NIV]. Two small respiratory unit studies have investigated agreement in patients undergoing NIV. Storre at al studied 10 patients reported an average difference of 4.6 mmHg with 95% limits of agreement from −3.9–13.2 mmHg.[8] Cox et al studied 22 patients reporting an average difference of approximately 1.5 mmHg with 95% limits of agreement from −6.75 mmHg to 4.5 mmHg. In addition, in laboratory tests, it has been reported that changes in $PtCO_2$ in response to acute progressive changes in $PaCO_2$ vary among subjects.[9]

Our aim is to determine agreement between $PtCO_2$ and $PaCO_2$ for patients undergoing NIV for respiratory failure in an emergency department [ED]. We hypothesised that $PtCO_2$ would have acceptable agreement with $PaCO_2$ [95% limits of agreement less than ±10 mmHg].

Methods

This prospective observational study including a convenience sample of patients undergoing NIV for respiratory failure [either chronic airways disease or acute pulmonary oedema] who required arterial blood gas analysis as part of their care. Patient management and NIV settings were at the discretion of the treating physician.

Data collected included patient demographics, indication for NIV, vital signs and $PaCO_2$ and $PtCO_2$. $PtCO_2$ was measured using a TCM4 series transcutaneous carbon dioxide monitor [Radiometer Medical ApS, Denmark] and arterial blood gas samples were analysed on a Radiopoint 405 [Siemens Healthcare Diagnostics Inc. NY, USA]. Probes were placed on the trunk, usually the upper chest, using the conductive solution as per manufacturer's instructions. Staff were instructed to wait at least 5 min after applying the transcutaneous sensor to allow equilibrium to be reached.

The primary outcome of interest was agreement between $PaCO_2$ and $PtCO_2$. Analysis was made using descriptive statistics, Bland-Altman techniques, Mann–Whitney *U* test, Fisher or Chi Square tests for comparison of proportions as appropriate and Spearman correlation for the relationship between CO_2 difference and pH. The institutional ethics panel waived requirement for patient consent.

Results

46 comparisons were analysed. Median age was 69 [IQR 65–79], 67% were male; median $PaCO_2$ was 60 mmHg [IQR 46–70] and median pH was 7.35 [range 7.22–7.46, 23 patients acidotic] [Table 1]. A scatter plot of the relationship between $PaCO_2$ and $PtCO_2$ is shown in Fig. 1.

Average difference between $PaCO_2$ and $PtCO_2$ was 6.1 mmHg with 95% limits of agreement −10.1–22.3 mmHg.

Table 1 Characteristics of sample.

Variable	Data
Gender	Male 29, 63%
Age [years]	Median 69, IQR 65–79, range 48–88
Diagnosis	COAD 31, 67% CHF/APO 15, 33%
FiO_2	Median 30%, IQR 30–40%, range 21–100%
Pulse rate [bpm]	Median 97, IQR 87–104, range 53–230
Systolic blood pressure [mmHg]	Median 131, IQR 117–151, range 96–100
O_2 saturation [%]	Median 94, IQR 90–97, range 66–100
Capillary refill time [secs]	Median 2, IQR 2–3, range 1–4. [missing data 10]
$PaC0_2$ [mmHg]	Median 60, IQR 46–70, range 33–91
pH	Median 7.35, IQR 7.30–7.38, range 7.22–7.45 Acidotic [pH <7.35], $n = 23$, 50%

[Fig. 2] Thirty seven comparisons [80%] were within 10 mmHg [95% CI 66–90%]. Difference >10 mmHg was associated with increasing $PaCO_2$ [$p = 0.001$; median difference 19.6 mmHg, 95% CI 9.2–30.4 mmHg], but not with pulse rate [$p = 0.74$], systolic blood pressure [$p = 0.60$], O_2 saturation [$p = 0.10$], capillary refill time [$p = 0.55$], diagnosis [$p = 0.75$] or pH [$p = 0.39$]. All cases with difference >10 mmHg had $PaCO_2 > 60$ mmHg. Correlation between CO_2 difference and pH was poor [r statistic 0.26, 95% CI −0.04–0.51].

Discussion

This study found an average difference between $PaCO_2$ and $PtCO_2$ of 6.1 mmHg, however the 95% limits of agreement

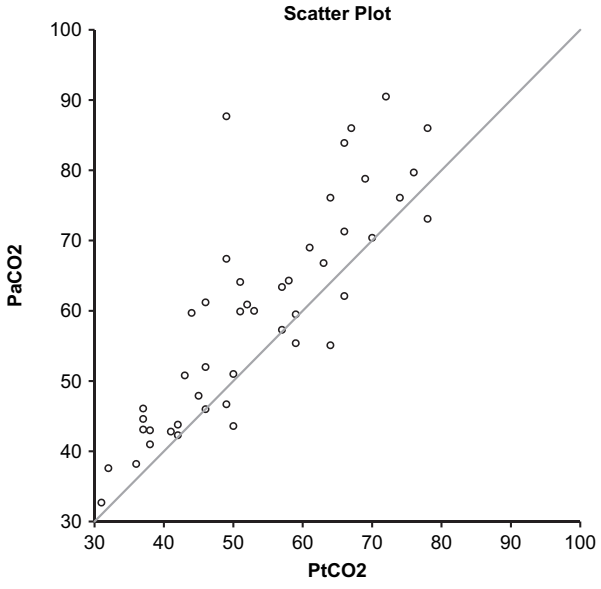

Figure 1 Scatter plot of agreement between $PtCO_2$ and $PaCO_2$.

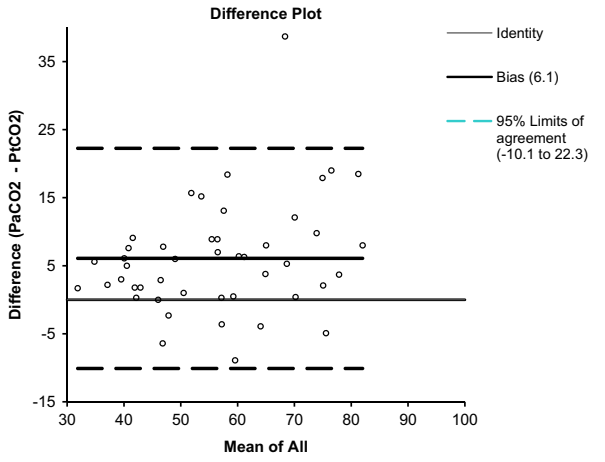

Figure 2 Bias plot of agreement between $PtCO_2$ and $PaCo_2$.

were wide [−10.5—23.5 mmHg] with $PaCO_2$ higher than $PtCO_2$. There was also significant between individual variation in the difference which could challenge clinical utility. Agreement was worse at higher $PaCO_2$.

Our findings are in contrast with previous ED studies. Perrin et al., in a study of patients with asthma or pneumonia, reported an average difference of −0.13 mmHg with 95% limits of agreement −3.9—3.7 mmHg.[5] It should be noted that this study excluded patients with respiratory failure which is the group targeted by our study. McVicar et al reported an average difference of 1.5 mmHg with 95% limits of agreement +/− 6.75 mmHg.[6] Our limits of agreement are also wider than the previous study of patients undergoing NIV.[7,8] Reasons for these differences might include the impact of acidosis of skin perfusion, differences in monitors used, differences in severity of illness and differences in staff training regarding device use. This study is also larger and more heterogeneous that the two previous studies of patients undergoing NIV so may be more likely to identify outliers.

Our finding that agreement between $PaCO_2$ and $PtCO_2$ to within 10 mmHg deteriorated at higher $PaCO_2$ levels with $PtCO_2$ underestimating $PaCO_2$ is important as the patient group requiring NIV are likely to have high $PaCO_2$ levels. This was also evident in the data reported by Storre et al,[8] but was not commented on by them. While the absolute value of $PaCO_2$ may have limited clinical value in isolation, the median difference between $PtCO_2$ and $PaCO_2$ of 19 mmHg at $PaCO_2$ levels >60 mmHg could falsely give the impression of near-normal $PaCO_2$ and adversely impact clinical decision making. An awareness of this would be necessary if $PtCO_2$ was in routine use for this group of patients.

For patients with respiratory failure requiring NIV, blood gas analysis is not a one off test. While an initial blood gas is usually obtained to measure $PaCO_2$ and pH, repeated analyses are usually required to assess progress. There is good evidence that venous pH is clinically equivalent to arterial pH.[10] Used in combination with venous pH, a potential role for $PtCO_2$ is in monitoring progress particularly changes in $PaCO_2$ over time. This is supported by the findings of Storre et al who reported that $PtCO_2$ trend reliably reflected the trend of change in $PaCO_2$ in patients undergoing NIV.[8] This was however a small study and further corroboration would be desirable.

This study has some limitations that should be considered when interpreting the results. It is a single centre study using a single monitor. The study included patients with respiratory failure from both pulmonary oedema and chronic airways disease. It is possible that there was a difference in performance between these groups that the subgroup sizes are not sufficient to detect. The acceptable limits of agreement of +/−10 mmHg were chosen arbitrarily, based on previous studies. A different definition would change the proportion of comparisons classified as acceptable. It is possible that patient factors such as body habitus, fever and sweating impacted monitor performance. We did not collect data regarding these.

Conclusion

In the NIV group of patients, agreement between $PaCO_2$ and $PtCO_2$ was sub-optimal, with wide 95% limits of agreement. $PtCO_2$ cannot be recommended as a substitute for $PaCO_2$ testing in this group. It may however have a role in monitoring trend and effectiveness of treatment.

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Conflict of interest and funding

This project was conducted using departmental funds only. Equipment was leased and the manufacturer did not provide any support to the project. In particular, they made no contribution to analysis or interpretation of the data. In 2009, Professor Kelly received support from Radiometer Pty Ltd to attend a conference.

References

1. Xue Q, Wu X, Jin J, Yu B, Zheng M. Transcutaneous carbon dioxide monitoring accurately predicts arterial carbon dioxide partial pressure in patients undergoing prolonged laparoscopic surgery. *Anesth Analg*; 2010 Jun 28 [Epub ahead of print].
2. Oshibuchi M, Cho S, Hara T, Tomiyasu S, Makita T, Sumikawa K. A comparative evaluation of transcutaneous and end-tidal measurements of CO_2 in thoracic anesthesia. *Anesth Analg* 2003;**97**:776—9.
3. Urbano J, Cruzado V, Lopez-Herce J, del Catillo J, Bellon JM, Carrillo A. Accuracy of three transcutaneous carbon dioxide monitors in critically ill children. *Pediatr Pulmonol* 2010;**45**: 481—6.
4. Stege G, van den Elshout FJ, Heijdra YF, van de Van MJ, Dekhuijzen PN, Vos PJ. Accuracy of transcutaneous carbon dioxide tension measurements during cardiopulmonary exercise testing. *Respiration* 2009;**78**:147—53 [Epub 2008 Dec 17].

5. Perrin K, Wijesinghe M, Weatherall M, Beasley R. Assessing $PaCO_2$ in acute respiratory disease: accuracy of a transcutaneous carbon dioxide device. *Intern Med J*; 2010 Feb 26 [Epub ahead of print].
6. McVicar J, Eager R. Validation study of a transcutaneous carbon dioxide monitor in patients in the emergency department. *Emerg Med J* 2009;**26**:344—6.
7. Kelly AM, Hanson D. Transcutaneous carbon dioxide monitoring in the emergency department: a pilot study. *Emerg Med [Fremantle]* 1991;**3**:259—62.
8. Storre JH, Steuer B, Kabitz HJ, Dreher M, Windisch W. Transcutaneous PCO_2 monitoring during initiation of noninvasive ventilation. *Chest* 2007;**132**:1810—6.
9. Fuke S, Miyamoto K, Ohira H, Ohira M, Odajima N, Nishimura M. Evaluation of transcutaneous CO_2 responses following acute changes in $PaCO_2$ in healthy subjects. *Respirology* 2009;**14**: 436—42.
10. Kelly AM. Can venous blood gas analysis replace arterial in emergency medical care?: a review. Emerg Med Australas, in press.