Use of mathematically arterialised venous blood gas sampling: Comparison with arterial, capillary, and venous sampling

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Introduction

Arterial blood gas (ABG) sampling is essential for patients treated with non-invasive ventilation (NIV). Sampling is painful, though local anaesthesia is rarely used in UK ward-based practice. Capillary (CBG) and venous (VBG) are alternative methods, though limited by reliability and accuracy concerns.

A newer Venous to Arterial Conversion method (v-TAC, Roche) is available. It calculates arterial acid-base status from VBG measurements combined with blood oxygen levels (SpO2) from a standard pulse oximeter. The peripheral venous blood is mathematically transported back through the tissues adding oxygen and removing carbon dioxide in a fixed ratio until oxygen levels match measurements taken from the pulse oximeter. The model accounts for the Bohr-Haldane effects in the blood, and for the oxygen dissociation curve to the plateau point (i.e. less accurate if SpO_2 > 97%).

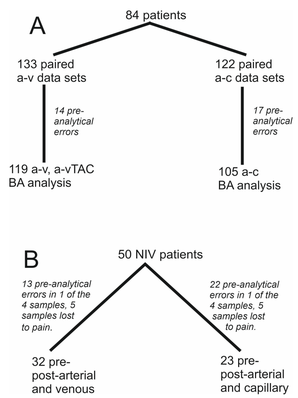
Prior studies confirm the accuracy and precision of arterial values calculated using v-TAC for pH and PCO_2 at all ranges, and PO_2 up to 10 kPa (higher values less accurate due to oxygen-dissociation curve characteristics).

In this study, we compare ABG sampling with v-TAC, CBG, and VBG in the longitudinal assessment of patients referred for NIV. The patient cohort comprised adults with known or suspected hypercapnic respiratory failure assessed on an inpatient basis to start home NIV. As such, we were most interested in the relative agreements for PCO_2 and pH.

Recruited patients underwent near simultaneous ABG, CBG and VBG sampling with contemporaneous pulse oximetry at day 0. If NIV was required, then sampling was repeated after the first night of NIV and on hospital discharge. Sampling was undertaken by routine clinical staff trained in each procedure. Participant experience of sampling was recorded using a standard visual/analogue pain score.

COI: The study was supported by an unrestricted grant from ObiMedical, Denmark (£30,000). After the study onset, ObiMedical became a subsidiary of Roche Diagnostics International.

Demographics (patients and sampling)



As shown in A, of 133 paired sets there were 119 samples available for Bland-Altman analysis (results shown in Figure 2). The pre-analytical errors included missed arterial sampling (venous admixture) for 8 samples.

As shown in B, 50 patients started NIV. Trend comparisons required all samples to be obtained (patient acceptance, successful sample, meeting prespecified criteria). For the ABG vs. v-TAC comparison, 32 patients were available and results are shown in Figure 3.

Figure 1: Demographic data. Mean age for the cohort was 63 years (SD 12 years), 45% female. Primary diagnoses were COPD (50%), obesity (26%), neuromuscular (17%), and others (7%).

	ABG	VBG (v-TAC)	CBG
SAMPLE SUCCESS RATES			
Success at first attempt (%)	67	88	55
Success by second attempt (%)	82	96	74
Success at 3+ attempts (%)	87	98	79
Sample failure or patient refusal (%)	13	2	21
Average attempts per patient to achieve sample success (n)	1.56	1.18	1.81
PAIN FROM SAMPLING			
Mean Pain score (SD)	4.3 (3)	2.4 (2.2)	1.3 (1.6)

Table 1: First time success rates were highest for venous / v-TAC sampling. Arterial sampling was not possible for 13% of subjects (either missed or patient refusal). Arterial sampling was more painful than venous / v-TAC ($p<0.0001$), which in turn was more painful than capillary ($p=0.01$).

Results

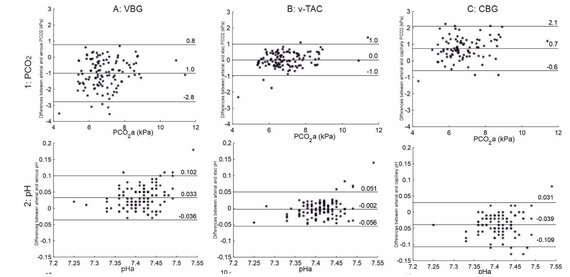


Figure 2: Bland-Altman agreement between ABG sampling and VBG (column A, n=119), v-TAC (column B, n=119), and CBG (column C, n=105) with respect to PCO_2 (row 1) and pH (row 2). Mean (SD) bias from ABG values was +1.00 (0.90) kPa for VBG (venous recording higher PCO_2), -0.01 (0.50) kPa for v-TAC, and -0.75 (0.69) kPa for CBG.

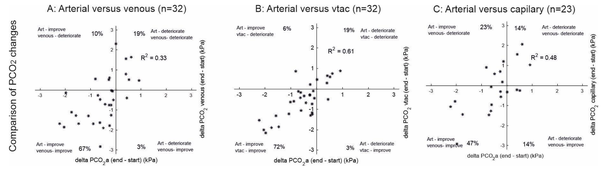


Figure 3: Arterial PCO_2 changes due to NIV compared to the changes seen for VBG (column A), v-TAC (column B), and CBG (column C). Categorical agreement for change in PCO_2 was 86% for VBG, 91% for v-TAC, and 61% for CBG. R^2 values were highest for v-TAC (0.61).

A separate study (*Shastri L, Scand J Trauma, Resus and ED 2021*) showed that the venous compartment is less susceptible to transient change in ventilation than arterial over a two-minute period. We undertook a post-hoc analysis in light of this study and found that 18/119 (15%) of arterial samples were potentially impacted by a transient change in ventilation (either breath-holding or hyperventilation).

CONCLUSION

v-TAC sampling showed good agreement with ABG and was easier and less painful. CBG and VBG showed poor agreement with ABG. Longitudinal analysis (pre and post NIV) suggests that v-TAC sampling could be used interchangeably with ABG in this cohort. These results challenge existing UK ward-based practice of repeated ABG sampling and the use of CBG as an ABG surrogate for patients requiring NIV.