The Journal of Emergency Medicine, Vol. 44, No. 3, pp. 709–716, 2013

0736-4679/$ - see front matter

ELSEVIER

http://dx.doi.org/10.1016/j.jemermed.2012.07.041

Brief Reports

IMPROVING THE VALIDITY OF PERIPHERAL VENOUS BLOOD GAS ANALYSIS AS AN ESTIMATE OF ARTERIAL BLOOD GAS BY CORRECTING THE VENOUS VALUES WITH SvO_2

Fabien Lemoël, MD,* Sandra Govciyan, MD,* Mouna El Omri, MD,* Charles-Hugo Marquette, MD, PHD,† and Jacques Levraut, MD, PHD*

*Emergency Department, Hôpital Saint-Roch, Nice, France and †Pulmonary Department, Hôpital Pasteur, Centre Hospitalier Universitaire de Nice and Université de Nice Sophia Antipolis, Nice, France

Reprint Address: Jacques Levraut, MD, PHD, Emergency Department, Hôpital Saint-Roch, 5 rue Pierre Devoluy, Nice F-06006, France

□ Abstract—Background: Peripheral venous blood gas (pVBG) analysis in replacement of arterial blood gas (ABG) is limited by the unpredictable differences between arterial and venous values, especially for PCO_2 and pH (ΔPCO_2 and ΔpH). Objectives: We hypothesized that, using the theoretical relationship linking SvO_2 and blood flow, we could diminish the effect of local circulatory conditions on ΔPCO_2 and ΔpH and thereby increase pVBG validity. Methods: This was a prospective cross-sectional study performed in emergency patients requiring a blood gas analysis in which ABG and pVBG were performed simultaneously. The data of 50 randomly selected patients (model group) were used for developing two equations to correct $PvCO_2$ and pHv according to the peripheral SvO_2 ($SpvO_2$) level. The formulas derived were $PvCO_{2cor} = PvCO_2 - 0.30 \times (75 - SpvO_2)$, and $pHv_{cor} = pHv + 0.001 \times (75 - SpvO_2)$. The validity of the corrected values was then tested on the remaining population (validation group). Results: There were 281 patients included in the study, mainly for dyspnea. ΔPCO_2 and ΔpH were strongly correlated with $SpvO_2$ ($r^2 = 0.62$ and $r^2 = 0.53$, respectively, $p < 0.001$). Using the data of the model group, we developed equations that we applied on the validation group. We found that the corrected values were more valid than the raw values for detecting a $PaCO_2 > 45$ mm Hg (AUC ROC = 0.96 ± 0.01 vs. 0.89 ± 0.02, $p < 0.001$), a $PaCO_2 < 35$ mm Hg (AUC = 0.95 ± 0.02 vs. 0.84 ± 0.03, $p < 0.001$), a pHa < 7.35 (AUC = 0.97 ± 0.01 vs. 0.95 ± 0.02, $p < 0.05$), or a pHa > 7.45 (AUC = 0.91 ± 0.02 vs. 0.81 ± 0.04, $p < 0.001$). Conclusions: The variability of ΔPCO_2 and ΔpH is significantly lowered when the venous values are corrected according to the $SpvO_2$ value, and pVBG is therefore more accurate and valid for detecting an arterial abnormality. **© 2013 Elsevier Inc.**

□ Keywords—acid-base; arterial blood gas; carbon dioxide; venous blood gas; bicarbonate; arterial puncture

INTRODUCTION

Arterial blood gas analysis plays an important role in interpreting metabolic and respiratory consequences of severe acute illness in the Emergency Department (ED). It is also an important tool for assessing the respiratory status of severe patients with a history of chronic obstructive pulmonary disease (COPD) admitted to the ED, regardless of the cause of their admission. Arterial puncture, however, is more time-consuming, more painful, and may lead to more complications when compared to venous puncture. Several studies have proposed the use of peripheral venous blood gas in replacement of arterial blood gas in the Emergency Medicine setting (1–14). However, most of these studies have shown that this method seems to be somewhat unreliable, especially for evaluating PCO_2, due to unpredictable discrepancies between arterial and venous values (2,7,9,13–18). Therefore, the substitution of venous blood gas for arterial blood gas could be

RECEIVED: 26 December 2011; FINAL SUBMISSION RECEIVED: 15 March 2012;
ACCEPTED: 3 July 2012

limited for patients in whom assessment of $PaCO_2$ is of great importance, such as those presenting to the ED with acute respiratory failure. Indeed, a method for correction of this discrepancy between arterial and venous PCO_2 would be of great interest, particularly in this category of patients.

Several factors may be at the origin of the variability of arteriovenous differences in PCO_2. First, tissue CO_2 production may be different from one patient to another. However, this factor is unlikely to be important when the venous sample is taken from the forearm, because the CO_2 production inducing change in $PvCO_2$ is then limited to the hand and the forearm tissues. The second factor that could explain this variability is linked to the local blood flow. According to the Fick equation, CO_2 may stagnate in the venous blood stream in the case of low blood flow, thereby increasing the gap between the arterial and the venous values (19). The decrease in forearm blood flow may be due to poor circulatory conditions, but may also be the consequence of tourniquet placement on the arm during venous blood sampling (20). In the case of low forearm blood flow, the local venous saturation of oxygen should decrease because local oxygen extraction increases to maintain local oxygen consumption.

We hypothesized that the gradient between arterial and venous PCO_2 (and pH) is mainly dependent on the local blood flow, which may be evaluated by the peripheral SvO_2 value ($SpvO_2$). Therefore, the goals of our study were:

- to check if the gradient between arterial and venous PCO_2 (and pH) is related to the $SpvO_2$ values
- to propose a correction of the venous PCO_2 and pH values according to the $SpvO_2$ level to control for the effect of local circulatory conditions on the variability of venous values
- to test the validity of this calculation in a sample of emergency patients

MATERIALS AND METHODS

Study Design

This was a cross-sectional study performed prospectively in patients presenting to the ED who required blood gas analysis. The patients included in the study were randomly divided into two groups: data from the first group of patients was used to construct a model for correction of PCO_2 and pH values (model group), and data from the second group was used to validate that model (validation group).

This study was approved by our local ethics committee and informed consent was obtained from each individual or relatives before inclusion into the study.

Study Setting and Population

This study was performed in a large urban ED with an annual adult census of 70,000.

All patients fulfilling the following criteria were eligible for inclusion in this study:

- Age > 18 years
- Need for arterial blood gas analysis, as decided by the overseeing attending physician, independently of the study.

Study Protocol, Measurements, and Data Collection

Eligible consenting adults were enrolled in the study by the physician treating the patient. Each patient enrolled had a venous blood sample taken from a peripheral venous catheter placed in the arm to start an infusion. Venous blood sample analysis included blood gas measurement (using a 1-mL blood gas syringe) and other examinations, according to the discretion of the attending physician in charge of the patient. Arterial blood gas measurement was made shortly thereafter by puncture in the radial or femoral artery.

Outcome Measures

The main objective of this work was to test the benefit of the correction of PCO_2 and pH values as a function of $SpvO_2$ to detect the presence of an abnormal arterial blood gas. Accordingly, the capacity of the raw venous PCO_2 and pH blood values to detect the presence of an arterial PCO_2 or pH abnormality was compared with that obtained from the values corrected by the $SpvO_2$.

Data Analysis

Statistical and data analyses were made using the StatView® (version 5.0; SAS Institute, Cary, NC) and the MedCalc® (version 11.1.0.0; MedCalc Software, Mariakerke, Belgium) software. Descriptive data are presented as means plus or minus SDs. A p value of < 0.05 was considered significant.

Relationship between arteriovenous gradients and $SpvO_2$. Delta pH (ΔpH) and delta PCO_2 (ΔPCO_2) were calculated as the difference between venous and arterial samples for the pH and PCO_2 for each patient:

$$\Delta pH = pHv - pHa$$
$$\Delta PCO_2 = PvCO_2 - PaCO_2.$$

The strength of the relationship between the ΔPCO_2 (or ΔpH) and the level of $SpvO_2$ was evaluated by calculating the determination coefficient (r^2).