TECHNICAL NOTE

Comparison of Arterial Blood Sample Kits

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Most inaccuracies in the analysis of gases and electrolytes in arterial blood samples are due to preanalytic factors, among which is the type of equipment used for blood collection. Our objective was to compare arterial blood gas sample kits used under clinical conditions and to evaluate the impact of delay in estimation on variability in results. In 2 types of study we compared 5 kits (Radiometer's Pico 70, Becton Dickinson's Preset, SIMS Portex's Pro-Vent, SIMS-Concord's Pulsator, and Marquest's Quick ABG). In the first study kit assignment was randomized for collecting arterial blood samples from 160 consecutive patients to evaluate practical aspects of using them and the presence of bubbles in the samples taken. The second study evaluated the effects of delays of 30 and 60 minutes in estimation and of the type of heparin used in 54 blood samples. The kits which produced the fewest bubbles, gave samples with the greatest stability, and had the least impact on ion concentration were Radiometer's Pico 70 and SIMS-Portex's Pro-vent.

Key words: *Arterial blood gases. Ionogram. Variability. Arterial blood sample kits.*

Comparación de equipos para obtener muestras de sangre arterial

La mayor parte de la variabilidad en la determinación de los gases y electrolitos en muestras de sangre arterial es "preanalítica", y la participación del tipo de equipos utilizados en la obtención de las muestras sanguíneas es fundamental. Nuestro objetivo fue comparar diferentes equipos de obtención de muestras, en condiciones habituales de uso clínico, y analizar el impacto del retraso temporal en la lectura sobre la variabilidad de los resultados. Comparamos 5 equipos (Pico 70 de Radiometer, Preset-Becton Dickinson, Provent-Sims de Portex, Pulsator-Concord y Quick A.B.G. de Markest) en 2 tipos de estudio. En el primer caso, valoramos el uso práctico y la presencia de burbujas, en 160 pacientes consecutivos, estudiados de forma aleatoria. En el segundo caso, analizamos el efecto de un retraso de 30 y 60 min en la lectura y el tipo de heparina que contienen los equipos, en 54 muestras sanguíneas. Los equipos con menor número de burbujas, con mayor estabilidad de las muestras y con menor impacto en la concentración de iones fueron el Pico 70 de Radiometer y el Provent-Sims de Portex.

Palabras clave: *Gases arteriales. Ionograma. Variabilidad. Equipos para muestras sanguíneas.*

Introduction

Blood gas and electrolyte analysis is common in hospital practice. In most instances an arterial blood sample is used to measure acid-base balance, and the gases are simultaneously used to determine the hydrogen ion concentration. In both cases measurement results are conditioned by the type of equipment used for sample collection and the length of time the sample is held prior to analysis.

Inaccuracies in blood sample readings have been studied at length, especially as part of kit manufacturers' quality control programs.[1] However, imprecision attributable to preanalytic factors, which account for most measurement inaccuracies, have been studied less. Accordingly, our objective was to evaluate several arterial blood gas sample kits available on the market in order to compare both their performance in normal practice and their tendencies to generate inaccuracies, especially variations due to delayed reading.

Patients and Methods

The present study was carried out in 2 parts to accommodate our dual objectives. For both parts we obtained the permission of our hospital's Ethics Committee and the informed consent of the patients. To evaluate the practical aspects of using the blood sample kits we studied 160 consecutive patients (117 men and

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Figure. The 5 blood sample kits compared: 1) Radiometer's Pico 70 (Copenhagen, Denmark); 2) Becton Dickinson's Preset (Franklin Lakes, NJ, USA); 3) SIMS-Portex's Pro-vent (Keene, NH, USA); 4) SIMS-Concord's Pulsator (Keene, NH, USA), and 5) Marquest's Quick ABG (Englewood, CO, USA).

43 women) whose mean (SD) age was 64 (11) years and who, for diverse reasons, had been referred to our laboratory for lung function tests that included arterial blood gas analysis. The procedure for obtaining the blood samples followed the guidelines of the Spanish Society of Pulmonology and Thoracic Surgery (SEPAR). One of the 5 tested kits was used with each patient according to randomized assignment. Extractions and readings were always performed by the same person. For each blood test the following data were recorded: *a)* the time required to draw 1.5 mL of blood; *b)* the number of attempts to locate the radial artery; *c)* pain intensity (indicated on an analog scale from 0 to 10 cm, where 0 indicated absence of pain and 10, maximum pain); *d)* the presence of bubbles at the cone end of the barrel; *e)* the presence of bubbles on the plunger; *f)* the time required to remove the bubbles; *g)* the presence of bubbles on the stopcock, and *h)* presence or absence of a postsampling hematoma at the puncture site.

In the second part of our study we evaluated a total of 54 arterial blood samples drawn from femoral artery catheters inserted for invasive hemodynamic monitoring. These cases involved chronic coronary disease with no suspected additional factors that could affect our study. Samples were collected and analyzed in random order, always by the same person. A sample was taken from each patient using each blood sample kit—a total of 5 samples per patient. Each sample was analyzed immediately, then at 30 minutes, and again at 60 minutes—with the syringes refrigerated at 4ºC while waiting.

We evaluated 5 kits readily available on the market: Radiometer's Pico 70 (Copenhagen, Denmark), Becton Dickinson's Preset (Franklin Lakes, NJ, USA; European representative; Becton Dickinson Vacutainer Systems Europa, Le Pont de Claix Cedex, France), SIMS-Portex's Pro-vent and SIMS-Concord's Pulsator (Keene, NH, USA; European representative: Smiths Medical International Ltd, Hythe, Kent, UK), and Marquest's Quick ABG (Englewood, CO, USA; European representative: Vital Signs, Barnham, West Sussex, UK) (Figure). All samples were evaluated using Radiometer's ABL-700 analyzer, which had been previously prepared and calibrated for standard laboratory conditions.

An analysis of variance and the Student *t* test for unpaired variables were used to compare the differences. A value of $P<.05$ was considered significant.

TABLE 1
Variables Analyzed in the First Part of the Study of 5 Blood Sample Kits*

	A, s	B, no.	C, cm	D/E, %	F, s	G, %	H, %
Pico 70	15 (6)	1.2 (0.5)	0.2 (0.6)	16/0	5 (3)	3	3
Preset	11 (5)	1.2 (0.5)	0.4 (1.2)	9/28	5 (4)	22	3
Pro-vent	11 (3)	1.2 (0.6)	0.1 (0.2)	6/9	5 (3)	6	0
Pulsator	15 (4)	1.6 (0.3)	0.2 (0.6)	9/72	13 (7)	50	6
Quick ABG	12 (3)	1.1 (0.3)	0.1 (0.2)	25/19	5 (2)	9	3

*Values in columns A through C and F through H are means (SD). Column A shows time (in seconds) to draw 1.5 mL of blood; B, number of attempts to locate the radial artery; C, pain intensity (in centimeters) on an analog scale from 0 to 10 cm; D, samples containing bubbles at the cone end of the barrel; E, samples containing bubbles on the plunger; F, time (in seconds) to remove bubbles; G, samples containing bubbles on the stopcock; H, patients presenting a postsampling hematoma at the site of puncture.

Results

The results of the first part of the study were the following: the mean number of seconds to draw 1.5 mL of blood was 13 (4); the mean number of attempts to locate the radial artery, 1.3 (0.4); the mean pain intensity level expressed by patients on a scale from 0 to 10 cm, 0.3 (0.7); bubbles were present at the cone end of the barrel in 13% of the sampling procedures and on the plunger in 25%; it took a mean 7 (5) seconds to remove the bubbles; bubbles were present on the stopcock in 18% of the procedures; and a small postsampling hematoma at the puncture site occurred in 3% of the patients. Table 1 shows the data corresponding to these variables for each of the blood sample kits compared. Differences in the kits regarding time required for blood extraction and number of attempts to locate the artery were not statistically significant. The rest of the variables analyzed, however, were significantly different—especially regarding the appearance of bubbles and the time required to remove them. Bubble removal was easiest with Radiometer's Pico 70 and SIMS-Portex's Pro-vent ($P<.05$).

Table 2 presents the data of the second part of the study—mean values of pH, $PaCO_2$, PaO_2, Na^+, K^+, Ca^{++}, Cl^-, glucose, carboxyhemoglobin, and methemoglobin. The differences in carboxyhemoglobin and methemoglobin values were not statistically significant. The Pico 70, the Pro-vent, and Marquest's Quick ABG showed greater stability of results over time, especially for $PaCO_2$, Na^+, and Ca^{++} ($P<.05$). All the kits compared gave significantly higher PaO_2 readings over time ($P<.001$).

Discussion

Our study showed that currently available kits for arterial blood extraction sufficiently satisfy requirements for speed and ease of sampling and quality of the blood sample obtained. Nevertheless, blood samples collected by the Pico 70 and the Pro-vent were of superior quality since they contained fewer bubbles and removing them was easier. The Pico 70, the Pro-vent, and the Quick AGB provided the most stable and the least contaminated samples during the second part of the study.

Preanalytic factors are the greatest source of inaccuracies in laboratory measurements.[3,4] At present

TABLE 2
Gas and Ion Measurements Corresponding to the 3 Times When Readings Were Taken*

Time	Kit	pH, mmol/L	$PaCO_2$, mm Hg	PaO_2, mm Hg	Na^+, mmol/L	K^+, mmol/L	Ca^{++}, mmol/L	Cl^-, mmol/L	Glucose, mmol/L	COHb, %	MetHb, %
Basal	1	7.431	38.5	81.7	134.3	4.0	1.3	104.4	6.7	1.6	0.7
	2	7.427	39.0	80.0	136.0	4.0	1.2	105.2	6.7	1.5	0.7
	3	7.431	38.5	82.5	134.1	4.1	1.3	104.3	6.7	1.6	0.7
	4	7.416	33.1	85.1	139.7	4.2	1.7	106.4	5.7	1.5	0.8
	5	7.426	39.3	80.2	133.1	4.0	1.2	103.8	6.6	1.5	0.7
30 minutes	1	7.428	38.7	83.6	134.3	4.0	1.3	104.8	6.6	1.5	0.7
	2	7.421	39.1	81.0	138.7	4.1	1.2	106.1	6.5	1.5	0.7
	3	7.428	38.7	84.4	133.8	4.0	1.3	104.4	6.6	1.5	0.7
	4	7.413	33.1	90.3	139.5	4.2	1.7	106.9	5.6	1.5	0.8
	5	7.418	39.7	84.1	133.2	4.0	1.2	104.3	6.6	1.5	0.7
60 minutes	1	7.427	38.6	87.5	134.2	4.1	1.3	105.0	6.5	1.5	0.7
	2	7.415	39.8	85.9	143.2	4.2	1.0	106.1	6.6	1.5	0.7
	3	7.425	38.8	86.3	133.9	4.1	1.3	104.7	6.5	1.5	0.7
	4	7.413	33.1	96.4	139.7	4.3	1.7	107.2	5.5	1.5	0.8
	5	7.412	40.0	88.2	133.5	4.1	1.1	104.6	6.5	1.5	0.7

*Row 1 shows results from Radiometer's Pico 70 (Copenhagen, Denmark); 2, Becton Dickinson's Preset (Franklin Lakes, NJ, USA); 3, SIMS-Portex's Pro-vent (Keene, NH, USA); 4, SIMS-Concord's Pulsator; 5, Marquest's Quick ABG (Englewood, CO, USA). COHb indicates carboxyhemoglobin; MetHb, methemoglobin.

the accuracy and precision of analyzers has reduced variability almost entirely to problems arising from the collection and manipulation of samples. This is the case with equipment for measuring gases and ions in arterial blood samples. A factor influencing variation in readings is the blood sample kit used. Therefore knowledge and evaluation of kits is fundamental to the quality control of measurements.

One of the most common preanalytic sources of inaccuracy is the presence of air bubbles in the syringe.[5] A syringe that draws samples with virtually no bubbles, has an efficient sealing mechanism, is made of material that discourages adherence of gases to the wall, and that facilitates removal of bubbles will be valued highly. The last feature was one of the outstanding characteristics of the Pico 70 and Pro-vent kits in the present study.

Another very important factor is the type of needle used for arterial puncture. The bevel edge should be short and very sharp in order to prevent damage to the artery wall, and the interior diameter of the needle should be wide enough to enable a rapidly drawn sample. These factors have a direct bearing on filling time and pain intensity. All the kits analyzed adequately fulfilled both criteria and no appreciable differences among them were noted.

Yet another noteworthy source of variability in the determination of ion concentrations is the presence of certain types of heparins in the equipment. Unbalanced calcium heparin can clearly modify calcium ion concentrations in a sample—as occurred in our study. The SIMS-Concord Pulsator consistently presented calcium and sodium concentrations that were higher than the mean due to the type of heparin that this device contained (liquid sodium heparin). This kit also resulted in the most variable long-term PaO_2 values, indicating environmental contamination; whereas the other kits provided more stable samples. Moreover the Pico 70 used a dry lithium/sodium balanced heparin that had no effect on hemoglobin and $PaCO_2$ values.

Delay in analyzing the sample can also significantly modify results. Our study, designed to evaluate the effect on readings of 30- and 60-minute delays in processing samples stored at 4ºC, indicated that delays had the most effect on PaO_2 values, which increased slightly, but that these delays did not significantly affect the measurements of other gases or electrolytes.

All told, the present study reveals the importance of using quality blood sample kits. Among the kits we evaluated, Radiometer's Pico 70 and SIMS-Portex's Pro-vent fulfilled the largest number of requirements. The effect of a 60-minute delay on ion concentrations is insignificant if suitable sample storage conditions are fulfilled. Such a delay does, however, have an impact on PaO_2 values. This underscores the importance of taking immediate readings of arterial blood samples.

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