
An Investigation of the Bentley^R Gas-STATTM Monitoring System GSM-100

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Abstract

(*J. Extra-Corpor. Technol.* 20(2):59–62) The Bentley^R Gas-STATTM monitoring system GSM-100 (GSM) is an optical fluorescence microsensing system with a sensor placed in the extracorporeal circuit. It measures blood temperature and analyzes oxygen tension, carbon dioxide tension, and pH at the actual blood temperature, and the results may be converted to values at 37°C.

In 6 pigs subjected to cardiopulmonary bypass at 28°C and 37°C, this system was compared to the Radiometer Acid-Base Laboratory-2 blood gas analyzer (ABL-2). A total of 102 blood samples were drawn from the arterial and venous lines of the circuit next to the GSM sensors, and simultaneously the GSM readings were recorded. The samples were analyzed by the ABL-2 at 37°C, and the results were converted to the actual temperature by the apparatus.

Statistical evaluation was performed by a linear regression model of ABL-2 readings on GSM readings. From preliminary analyses of the results, it appeared that for each of the three parameters all the data might be pooled into one regression.

The results indicated that the agreement between ABL-2 readings and GSM readings with respect to pO₂ and pCO₂ were only fair though not clinically acceptable. The correlation between GSM readings and ABL-2 readings of pH were poor and the GSM readings without clinical relevance.

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Introduction

Monitoring of blood gases and acid-base status during cardiopulmonary bypass (CPB) has for years been performed by analyzing blood samples by means of blood gas analyzer. Recently the Gas-STATTM Monitoring System GSM-100 (GSM)^a was introduced for in-line monitoring of these parameters during CPB. In a series of animal experiments we evaluated the performance of this system as compared to our routine measurements with the Radiometer Acid-Base Laboratory-2 (ABL-2)^b.

Materials and Methods

The GSM^a uses optical fluorescent microsensing technology for continuous in-line monitoring of blood gases, pH and temperature. Sensors containing fluorescent microsensors are placed on cells in the arterial and venous lines of the extracorporeal circuit. The microsensors are separated from the blood only by a membrane, which is permeable to oxygen, carbon dioxide and hydrogen-ions.

From the monitor filtered light is transmitted through fiber optic bundles to the sensors. The microsensors then emit light depending on the content of oxygen, carbon dioxide and hydrogen-ions. This light is returned to the monitor through receiving optical fibers, and the amount of light is measured. The actual temperature of the blood is registered through thermistor contact discs, which are contained in the sensors.

The time response of the GSM is = 1½–2 min. The sensors are calibrated by special calibration device using tonometered gases, before they are fitted into the cells in the circuit.

a American Bentley, Irvine, CA 92714.

b Radiometer, DK-2400 Copenhagen NV, Denmark.

The evaluation of the GSM against the ABL-2^b analyzer was performed in 6 healthy pigs weighing 30–40 kg. The extracorporeal circuit included a single venous cannula in the right atrium, a bubble oxygenator (Polystan, VT 5000^c), a conventional roller pump (Polystan^c), and an arterial cannula placed in the ascending part of the aorta. The circuit was primed with lactated Ringers solution and homologous blood, and the hematocrit was kept at 20–30 percent during the experiment. Flushing of the circuit with carbon dioxide, which might influence the results, was not used.

The animals were subjected to cardiopulmonary bypass at 37° and 28°C. The blood flow was 100 ml/kg/min, and the blood/gas ratio in the oxygenator was kept constant at 1:1.

Next to the GSM cells in the extracorporeal circuit, sampling ports were placed for withdrawal of blood for the analysis by the ABL-2. The automatic calibration of the ABL-2 analyzer was checked regularly during the experiment.

During CPB the GSM readings were recorded at the actual blood temperature and after correction by the monitor to 37°C. Blood samples were withdrawn simultaneously with the recording of the GSM readings. The samples were analyzed immediately in the same room by the ABL-2. The measurements were performed at 37°C and corrected by the machine to the actual blood temperature at the sampling site.

Statistical analysis of the observations was performed by computer plottings of ABL-2 values on GSM values, and by comparison of the regression lines with the line of identity. A significance level of 0.05 was used in all evaluations.

Results

A total of 102 blood samples were withdrawn and analyzed by the ABL-2 at 37°C (Table 1). 95 of these were corrected to the actual temperature; in the remaining 7 cases, the correction was interrupted by the automatic calibration of the machine. For each of these 197 sets of ABL-2 data corresponding GSM data were available.

Computer plottings of ABL-2 values on GSM values were performed for groups of data representing all pO₂ readings (Figure 1), all pCO₂ readings (Figure 2) and all pH readings (Figure 3). Then the data of pO₂, pCO₂ and pH were further evaluated by performing separate computer plottings of the following subsets of data: all arterial readings, all venous readings, all readings at normothermia, at 37°C, and all readings at actual temperature. Regression lines for the clinically most important subsets of data were performed, shown in Table 2, and described below.

^c Polystan A/S. DK-2750 Ballerup, Denmark.

Table 1

Sampling sites for 102 blood samples which were analyzed by the Radiometer Acid-Base Laboratory-2. 95 sets of results were corrected by the machine to the actual blood temperature. n: number of samples.

Sampling site	37°C	Actual temp.
	n	n
Arterial line, normothermia	28	26
Arterial line, hypothermia	30	28
Venous line, normothermia	29	26
Venous line, hypothermia	15	15
	102	95

In Table 2 the slopes and intercepts of all the regression lines are shown together with corresponding values of standard errors (SE). 95% confidence intervals may be calculated from the individual values $\pm SE \times 2$.

In the last column of Table 2, SD denotes the standard deviation about the regression line. The estimated error in Y_{ABL} for a reading X_{gas-STAT} ($Y = ax + b$) is $Y \pm 2 \times SD$ (95% confidence interval). Figure 4 shows the computer plottings of pO₂ readings in the physiologically most interesting area below 100 mmHg. All these data come from the venous sensor, because all arterial pO₂ readings were above 101.

pH: The regression line related to all pH readings (Figure 3) had an intercept of 4.4 and a slope of 0.40, i.e. markedly different from the line of identity. The GSM values are generally much higher than the ABL-2 values. Comparing the regression line of arterial pH readings to the regression line of venous pH readings showed a significant difference, so the correlation between the ABL-2 and the GSM readings of pH was poor and there was even a difference between the sensors on the arterial and venous lines.

pCO₂: Computer plottings of all pCO₂ readings are seen in Figure 2. The slope of this regression line (Table 2) is significantly different from the slope of the line of identity. The regression line for arterial readings is significantly different from the regression line for the venous readings of pCO₂.

Table 2

The regression lines: $Y_{ABL} = b_0 + b_1 \times X_{Gas-STAT}$ their intercepts, slopes, standard errors, number of plottings and the determination coefficients.

	Intercepts		Slopes		n	r ²
	b ₀	SE(b ₀)	b ₁	SE(b ₁)		
pO ₂	17.6	1.70	0.97	0.01	197	0.99
pCO ₂	1.1	1.00	0.91	0.03	197	0.86
pH	4.4	0.23	0.40	0.03	197	0.48

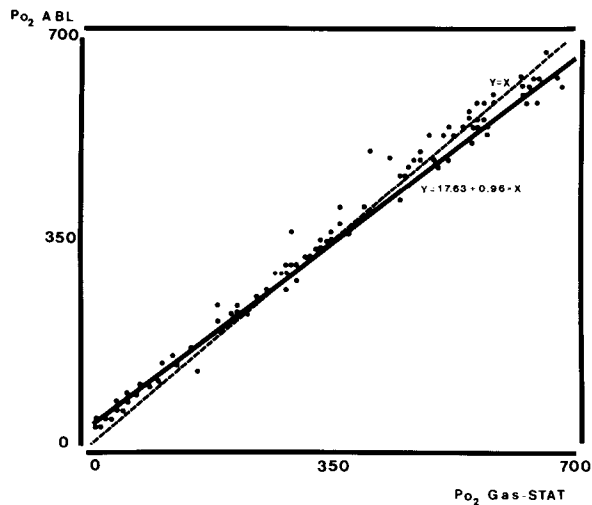


Figure 1A. Computer plotting of all pO₂ readings. The regression line with slope and intercept and the line of identity are shown.

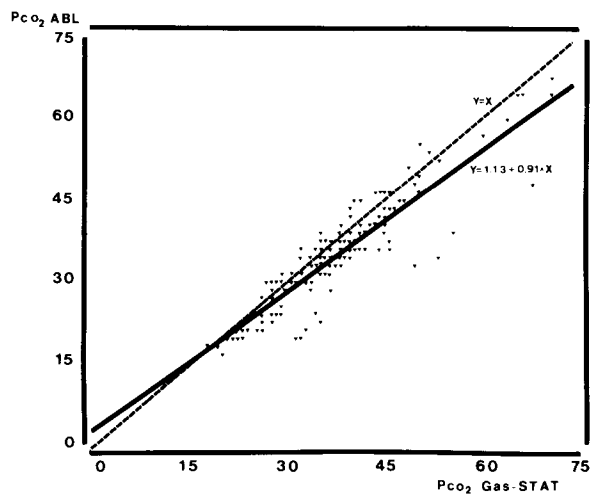


Figure 2. Computer plottings of all pCO₂ readings. The regression line with slope and intercept and the line of identity are shown.

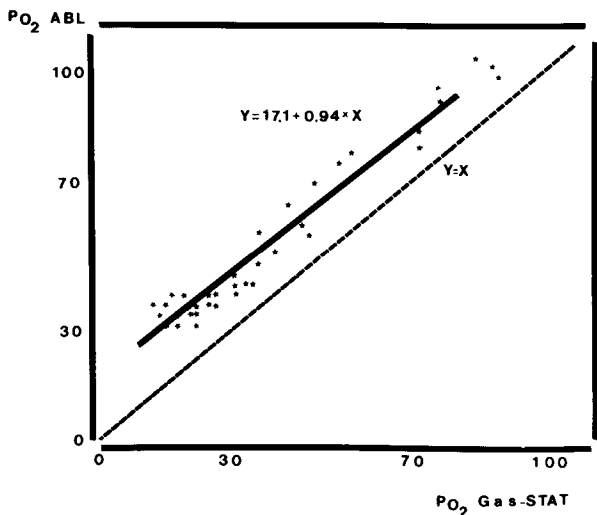


Figure 1B. Computer plottings of pO₂ readings below 100 mm Hg. The regression line with slope and intercept and the line of identity are shown.

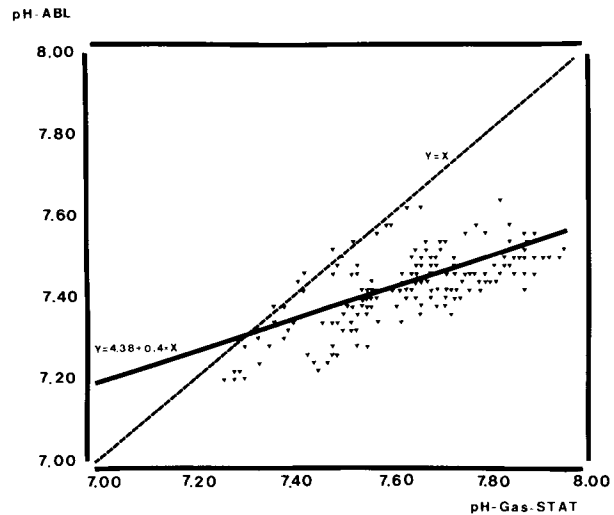


Figure 3. Computer plotting of all pH readings. The regression line with slope and intercept and the line of identity are shown.

pO₂: All pO₂ readings are plotted in Figure 1. The corresponding regression line (Table 2) was found significantly different from the line of identity. Then following supplementary analyses were performed: the regression line for all pO₂ data collected at 37°C was compared to the regression line for all pO₂ data collected at actual temperature. There was a significant difference between the slopes of these lines.

The regression line for all pO₂ data collected at normothermia was compared to the regression line for all pO₂ data collected at hypothermia. There was no significant difference between the slopes and intercepts of the lines on the 5% level.

The regression line for all arterial pO₂ readings was

compared to the corresponding venous line. There was no significant difference on the 5% level.

Discussion

Monitoring of blood gases and acid-base status with a conventional blood gas analyzer involves transportation of blood samples from the patient to the apparatus. Calibration of the analyzer further adds to the time between the sampling of blood and test result. When using an in-line monitoring system this delay is avoided; adjustments of the CPB can be made immediately when the need is reflected by in-line readings.

Grip et al.¹ reported a good correlation between Radiometer ABL-4 readings and GSM readings of pO₂, pCO₂ and pH. However, it was pointed out that the GSM was too slow to catch up with the rapid changes that occurred during cooling and rewarming.

In our study data were collected during steady state periods of the CPB. Before each experiment the calibration of the GSM was found to be within the limits given in the operator's manual; therefore, malfunction of the apparatus was not indicated. The participants of the study were familiar with the apparatus before initiation of the experiments. Our results showed a very poor agreement between the ABL-2 and GAS-STAT readings of pH. During stable and uneventful CPB the GSM readings were consistently much higher than the ABL-2 readings; some GSM readings were above 7.9, while the ABL-2 values were within normal ranges. This indicates that it was the GSM readings that were incorrect.

According to the statistics of the regression line to all pCO₂ readings (Table 2) a reading of 35 mm Hg on the GAS-STAT can approximately correspond to anything between 25 and 40 mm Hg on the ABL. This clinically unacceptable difference can be partly due to the sampling of data from different animals which means different sensors, partly due to differences in sensors used in the venous and arterial lines because the regression lines

from venous readings of pCO₂ are significantly different from the regression lines from arterial pCO₂ readings. Because these sensors are both compared to the ABL-2 that must be considered as a constant in this connection, the arterial and venous sensors must be considered as different.

Concerning the pO₂ readings: The regression lines for arterial and venous readings were not statistically different. But it is difficult to rely on this comparison between the arterial and venous sensors because all pO_{2A} values lie between 101 and 677 mm Hg and all pO_{2V} values lie between 13 and 103 mm Hg.

In the physiologically most interesting area of pO₂ up to 100 mm Hg (Figure 4) all ABL-2 readings are higher than GAS-STAT readings. This means that it would be safe to use the GAS-STAT in this area. But here as well as in other situations regarded in our study, with the exception of high values of pO₂, the use of the GSM would not be clinically acceptable.

References

1. Grip, A. et al. Continuous monitoring of arterial and venous blood gas parameters during cardiopulmonary bypass. Annual Meeting of the Scandinavian Association for Thoracic and Cardiovascular Surgery, Odense, 1985.