Continuous Blood Gas Monitoring Using the CDI System 300

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Abstract

The virtues and benefits of continuous on-line, real-time blood gas monitoring cannot be successfully denied, or its need be dismissed, on the basis of unavailable technology.

Not electing to monitor blood gases continuously is parallel in thought to not continuously monitoring arterial blood pressures or the electrocardiogram. Given the ever changing pH, and the fluctuation of the pC02 and pO2, we are never really sure of the trending that occurs during periods of low flow, temperature, and the myriad of other factors which affect acid/base balance.

In order to be fully informed as to the total status of the patient, it is of the utmost importance to recognize continuous blood gas monitoring as an adjunct to cardiopulmonary bypass and not just a luxury option. The CDI System 300 continuously monitors arterial and venous pH, pCO, pO2 and calculates HC03/B.E., and SvO2 while storing the hematocrit. With virtually effortless calibration and insignificant set-up time, the perfusionist can create a wide margin of safety for himself and quality perfusion of the patient, as well as providing the minimum standard care.

Introduction

Better perfusion techniques and state-of-the art technology have provided the patient with extra-corporeal circulation (ECC) that is safer than at any other time in past medical history. In order to maintain that margin of safety, and achieve a higher level of excellence in the clinical setting, on-line, real-time, continuous blood gas monitoring is imperative.

The perfusionist should no longer have to wait for randomly sampled results from the hospital laboratory or need to guess what the pO2 value is during hypothermia. Radical changes in pH as a result of long aortic cross-clamp can greatly affect the quality of perfusion and increase post-bypass related complications.

The CDI System 300 allows the perfusionist to apply scientific reasoning to known data and compensate for physiological changes.

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Methods and Materials

The CDI System 300 differs from the System 200 in that it calculates values for the arterial base excess, arterial bicarbonate concentration, and venous oxygen saturation. The System 300 also incorporates a programmable printer which allows for documentation. The fiber-optic cables are less cumbersome than the previous model and the thumbscrew bolts have been modified to prevent overtightening, thereby averting possible damage to the sensor and cell.

The System 300 operates on the same principle of fiber-optic fluorescence as did the System 200. The flow-thru cell contains a membrane that permits gas and hydrogen ion exchange, while providing a sterile barrier between the sensor and the blood. The sensor fits into the cell and contains fluorescent chemicals.

Light pulses originating from a flash lamp located in the monitor are passed through optical filters so that pulses of a specific color are transmitted down the fiber-optic bundles to the sensors. The sensors contain fluorescent chemicals which emit light in response to the stimulating pulses. The intensity of this emitted light depends upon the concentration of oxygen, carbon dioxide, and hydrogen ions passing through the gas and ion permeable membrane of the cell which separates the sensing chemicals from the blood. The light emitted by the fluorescent sensors is returned to the monitor through receiving optical fibers in the fiber-optic bundle. A filter is used to isolate the specific colors of interest from the returning light spectrum for measurement by a light detector.

The output signal of the detector is converted by the microprocessor to a numerical readout in millimeters of mercury, kilopascals, or pH units which is then displayed on the face of the monitor.

Prior to calibration, the on-board printer can be programmed to record the blood gases at any time-desired interval. This interval can be changed at any time during the bypass procedure without affecting the calibration of the unit. After calibration and insertion of the sensors into the circuit, the prime is recirculated for approximately 5 minutes to allow the monitored parameters to achieve equilibrium. The acid/base concentration of the prime is

observed to insure as near a normal physiological environment as possible. We have elected to use the option of on-line power by plugging the CDI System 300 into the junction box mounted to the base of the Pemco heart-lung machines in order to conserve the battery power. The monitor is left in the operative mode rather than "standby." This technique appears to aid in achieving more accurate results at the onset of bypass.

Approximately 15 minutes after the initiation of bypass blood samples are drawn and sent to the lab for analysis. These results are checked against the stored values derived from the System 300 and in-vivo recalibration is done only if the two sets of values differ by 5 percent. The printer is programmed to document the results every 15 minutes which aids in trending the data for studies at a later date. This technique provides a precise method of observing the trend and fluctuation.

Discussion

The key to accurate trending with this device is proper calibration and technique in use. The care and concern taken in calibration is directly proportional to accuracy achieved in the results. While calibration is fully automated and virtually free from human error, lack of patience on behalf of the operator is the reason most often responsible for poor performance. A proper technique must be developed in order to derive maximum efficiency. By insuring proper filling of the cells, and keeping the flashlamp on during the pre-bypass period, we are able to accurately monitor all the vital parameters on a continuous basis.

The CDI System 300 is not only a diagnostic device, it can be used therapeutically as well. Prior to initiating bypass the prime can be observed for acid/base balance and bicarbonate added if necessary. Excessive carbon dioxide can be swept from the bypass circuit by increasing the flow rate of oxygen. If the patient about to be placed on bypass has a known oxygen deficit, the prime can be saturated to any desired level and thereby deliver adequately oxygenated blood immediately at the onset of bypass with no lag time. Once on bypass, a metabolic or respiratory acidosis/alkalosis can be addressed and properly treated by either increasing blood flow, increasing or decreasing the sweep gas, adjusting the FI02, or adding sodium bicarbonate. There is no more guess work or speculation.

On-line, real-time, continuous blood gas monitoring should not to be considered a luxury; but rather an absolute necessity in providing the minimum standard of care for the patient while on cardiopulmonary bypass.

Results

A total of thirty-five (35) patients were randomly selected with no exclusions; 30 (86%) were male and 5 (14%) were female. The mean age was 59.1 while ejection fractions ranged from .14 to .60 for a mean .42. Patient weights ranged from 58 kilograms at the lightest end of the spectrum to 140 kilograms at the heaviest resulting in a mean of 85.9 kilograms. Sixty percent (60%) of the patients were seen for repeat revascularization. Twenty-three percent (23%) of the patients were placed on cardiopulmonary bypass (CPB) utilizing the Bentley BCM-7 oxygenator while the remaining 77% perfusions were accomplished employing the Bard HF-4000. Pump times ranged from 110 minutes to 420 minutes for a mean of 306 minutes. Blood flow rates ranged from 3.7 liters per minute to 5.5 liters per minute for a mean of 4.8 liters per minute. Sweep gas averaged 4.3 liters per minute while FI02 settings averaged 47%. It should be noted here that the BCM-7 required higher sweep gas rates and higher FI02 settings in order to achieve normal physiological blood gases at 34 degrees Centigrade.

Blood gas sampling was done on an hourly basis and analyzed on a Nova-Stat Profile computerized system based in the hospital laboratory. These results were then compared to the CDI System 300 which was programmed to sample and store the data every 15 minutes. Arterial, as well as venous blood gases were monitored and sampled. Both systems are calibrated by two-point gas tenometry.

Histograms 1 through 4 indicate the average of the differences between the two measured methods. Arterial and venous pH and pCO_2 values are combined since they fall within the same range of values. Arterial pO_2 values are expressed as the percent difference between the lab and the System 300 values, with the lab value taken as the reference value.

	pH	pCO2	PaO2	PO2
Mean	0.01	0.7	0.8	-1.1
S.D.	0.03	3.2	17.4	4.4
N:	319	319	162	156

There were 16 data points excluded from the analysis because of apparent deviations from accepted procedure (e.g. absent lab data, inaccurate recalibration, and HI or LO readings from the monitor). The histograms show how frequently a certain difference between the blood gas lab and the monitor occurred. For example, looking at the pH histogram shows that out of 319 trials, the difference between the lab and the System 300 was +0.01, etc.

To summarize the data in a simpler form, is to say the CDI System 300, when compared to the laboratory based blood gas analyzer, is well within the +3% range of compared accuracy providing proper calibration and technique is employed by the operator (Table I).

References

1. Rubsamen MD, LLB, David S.: Continuous blood gas monitoring during cardiopulmonary bypass-how soon will it be the minimum standard of care. Journal of Cardiothoracic Anesthesia, Vol. 4, No 1 (February), 1990: pp 1-4.

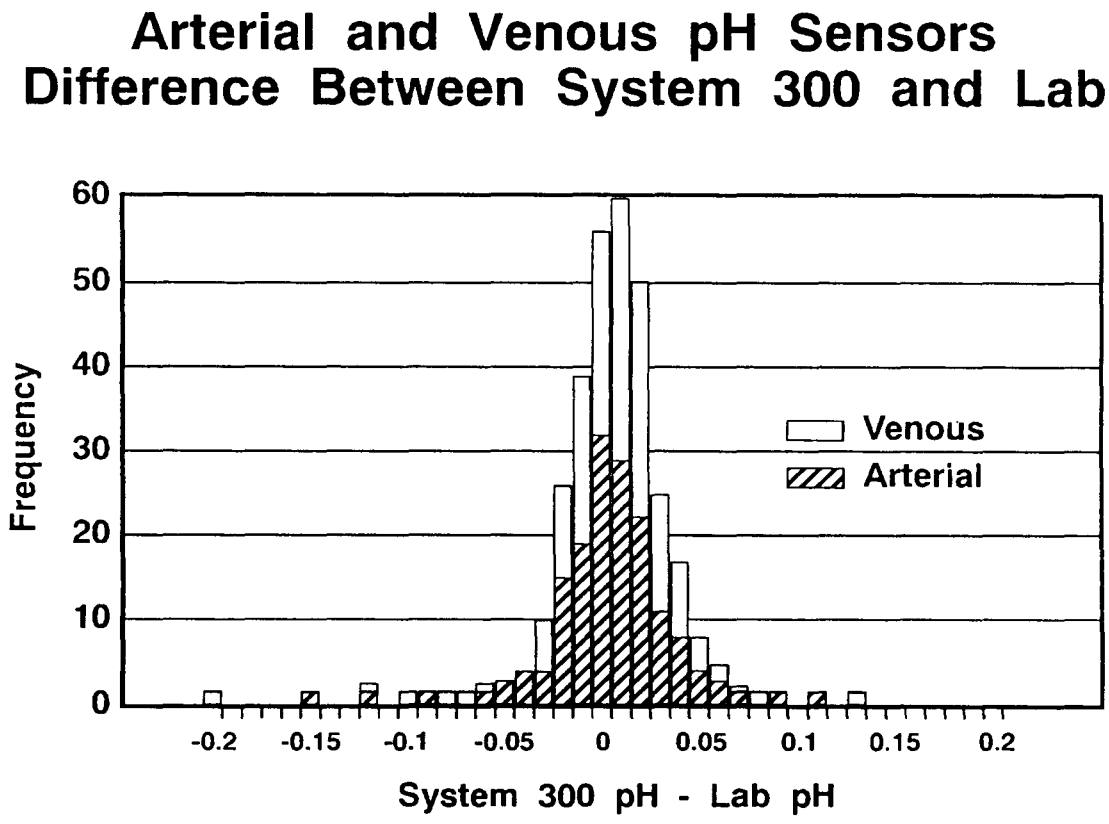
Table 1
(mean values ± standard deviation)

	CDI System 300	NOVA-STAT
(a) pH	7.44 ± .02	7.42 ± .01
PaCO2 (mm/Hg)	39 ± 6	43 ± 4
PaO2 (mm/Hg)	137 ± 15	119 ± 12
(v) pH	7.39 ± .01	7.37 ± .02
PvCO2	44 ± 2	45 ± 2
PvO2	27 ± 3	31 ± 6
SvO2 (%)	63 ± 5	68 ± 4

Table 2

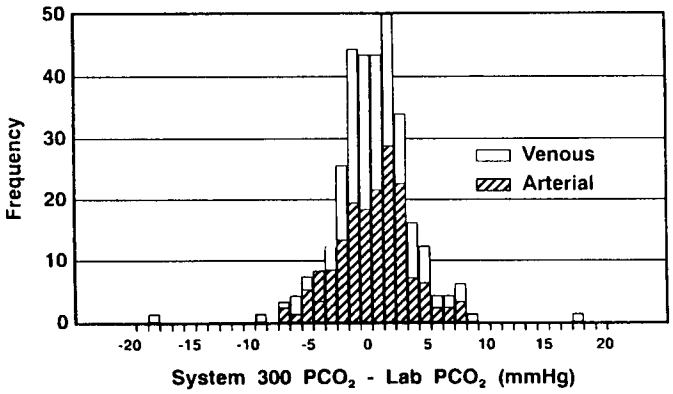
Male	30 (86%)
Female	5 (14%)
Age	59.1 y/o
Ejection Fraction	.42
Weight	85.9 kg
Percentage of Revascularization	60
Pump Time	306 min.
Blood Flow Rates	4.8 L/min
FIO2	47%

HISTOGRAM I



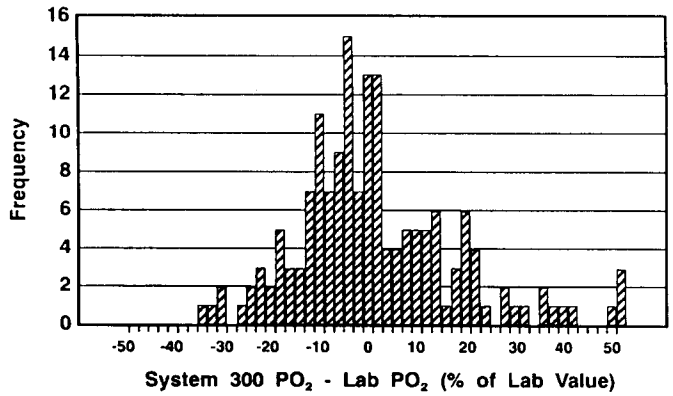
HISTOGRAM II

Arterial and Venous PCO_2 Sensors Difference Between System 300 and Lab



HISTOGRAM III

Arterial PO_2 Sensors Difference Between System 300 and Lab



HISTOGRAM IV

Venous PO_2 Sensors Difference Between System 300 and Lab