CON: IS CONTINUOUS INTRA-ARTERIAL BLOOD GAS AND pH MONITORING JUSTIFIABLE?

J. Lee Hoffer, PhD, MD,1 and Edward A. Norfleet, MD2


INTRODUCTION

One of the most recent monitoring innovations is the development of intra-arterial blood gas (IABG) systems. These devices utilize an ingenious system that transmits specific wavelengths of excitation light through an optical fiber to an electro-optic sensor in the blood that is sensitive to changes in the parameter being measured. In fluorescence-based sensors, the excitation light initiates fluorescence emission where the intensity varies as a function of the concentration of the analyte (O2, CO2, or H+). The emitted light from the sensor returns through an optical fiber to a microprocessor in the monitor. In absorption-based electro-optic sensors, the light absorbing characteristics of the chemical matrix change as a function of the analyte concentration. Three manufacturers in the United States have developed intra-vascular systems: (1) Paratrend 7 Intravascular Blood Gas Monitoring System by Biomedical Sensors, Ltd., Malvern, PA: the only currently available system; (2) PB3300 Intra-Arterial Blood Gas Monitoring System by Puritan Bennett, Inc.: commercially available in 1993, production discontinued in January 1994; and (3) Biosentry Continuous Intra-Arterial Blood Gas Monitoring System by Optex Biomedical Inc.

Can the use of continuous IABG systems be justified? The ability to collect more data at the bedside at first seems appealing, but will this new information really enhance the quality of care, affect mortality and morbidity, or significantly alter the outcome? Will IABG systems replace other noninvasive technology such as pulse oximetry (SpO2) and end tidal carbon dioxide (etCO2)? Are we duplicating measurements of oxygenation, ventilation, and perfusion? What is the cost versus benefit in time, effort, equipment, reliability, manpower, and outcome? Which patients would benefit most?

For almost 40 years, ABG analysis has been the gold standard and an indispensable tool in managing critically ill patients. With time, the laboratory technology has become more sophisticated, and made the results rapidly available. The introduction of SpO2 and etCO2 has provided continuous indications of oxygenation and ventilation that are reliable, easy to use, and most importantly, noninvasive.

Regardless of the technology, our most important monitoring resources are the highly trained critical care specialists, including technicians, nurses, and physicians.
who constantly provide vigilance and care at the bedside and assimilate the acquired data. Together, the machine and the human monitors provide complementary information that increases the quality of patient care and decreases the risk of mortality, morbidity, or untoward events. As new monitoring devices are introduced, however, overlapping functions, redundancy, and integration of multiple parameters may occur. Consequently, because of the escalating fiscal restraints and the increased emphasis on important but vague factors such as cost-benefit, potential risk-benefit, and reliability, the acquisition and processing of physiological data are being scrutinized.

For example, the need for serial or multiple arterial blood gas analysis (ABG) on an intermittent basis has been reduced because other monitors provide direct and continuous indications of the patient’s cardiorespiratory status [1, 2]. Monitoring systems and data processing have evolved to a level of sophistication in which cardiorespiratory trends can be confidently followed, therapeutic changes in life-support equipment can be precisely controlled, and the dynamics of patient-machine interactions can be safely titrated for the vast majority of patients. Therefore, the need for an intermittent ABG or the routine use of an IABG system has been greatly reduced.

Most anesthesiologists routinely employ SpO2 and etCO2 monitoring in the OR and many intensivists also use them in the ICU. Many facilities also have individual respiratory gas monitors or shared mass-spectrometer systems as well as STAT laboratories (for ABG, hemoglobin, and electrolytes) in or immediately adjacent to the OR and the ICU.

Fleisher and Schwartz [3] documented the turnaround time for urgent blood gas measurements in central and satellite laboratories in U.S. Hospitals as 19 and 8 minutes, respectively. In one large hospital where a pneumatic tube system transports blood specimens to the central laboratory and results are transmitted to remote computer terminals, Winkelman and Wybenga [4] found that the mean turnaround time for approximately 22,000 blood gas measurements in the central laboratory was 6 and 4 minutes for routine and urgent specimens, respectively, compared to 4–5 minutes for a satellite laboratory in the neonatal ICU. The total cost per reported result was $3.54 vs. $8.98 for the central and satellite laboratories, respectively.

The ability to monitor perfusion and oxygenation continuously far exceeds the need to measure ventilation. Thus, of the parameters (pH, PaO2, PaCO2, and temperature) that an IABG measures, PaO2 is by far the most critical. Changes in PaCO2 and pH are also important, but clinical experience has shown that variations in PaCO2 and pH are tolerated quite well (except in the very critically ill patient), provided oxygenation and adequate perfusion are maintained. Furthermore, under most clinical circumstances, if perfusion and oxygenation are well maintained, the PaCO2 and pH will remain stable.

In the majority of patients, there does not seem to be a significant advantage with the PaO2 from the IABG sensor over SpO2. The PaO2 is related to the SpO2 in a non-linear manner, as indicated by the sigmoid shape of the O2-hemoglobin dissociation curve. The linear portion of the curve is in the range of critical clinical importance where the SpO2 of 75–100% corresponds to a PaO2 of 38–95 torr.

In contrast to the IABG system, the newer pulse oximetry units include several clinically useful features: (1) the SpO2 is displayed continuously; (2) most units have a bar-graph indicator of the signal quality that correlates with perfusion of the extremity where the sensor is located; (3) the analog waveform of the SpO2 is affected by factors that alter blood flow to the extremity such as hypothermia, hypovolemia, vascular obstruction or constriction, and decreased cardiac output; (4) the waveform also gives an indication of the quality (dP/dT) of blood flow and changes in cardiac output (e.g., secondary to arrhythmias); and (5) adjustable alarm limits are available for both the SpO2 and heart rate. The delayed and intermittent PaO2 from an IABG unit offers little advantage over pulse oximetry in the clinical management of most critically ill patients.

In an intubated patient, the etCO2 correlates with PaCO2 (a typical differential of 3–8 torr). Unlike the single value for PaCO2, the etCO2 and the breath-by-breath CO2 waveform provide other vital information. On a breath-by-breath basis, benefits of such a respiratory function monitor include: (1) the etCO2; (2) a CO2 waveform; (3) an indication of both inspired and expired CO2; (4) an indication of respiratory dysfunction (e.g., airway obstruction, bronchial constriction, etc.); (5) obstruction of the endotracheal tube or breathing circuit; (6) dysfunctional valves in the anesthesia circuit; (7) ventilatory failure; (8) disconnection in the ventilator circuit; (9) significant changes in the PaCO2 (e.g., malignant hyperthermia, CO2 insufflation for laparoscopic procedures, hyper- or hypoventilation, etc.); (10) cardiovascular dysfunction; (11) misplacement of the endotracheal tube; and (12) an early indication of returning diaphragmatic function as neuromuscular blockade resolves.

Thus, the etCO2 and its associated monitoring system provide much more information concerning CO2 dynamics than the PaCO2 from the IABG.

The IABG provides a continuous (though delayed) indication of intravascular pH. Significant acute changes