CLN'S LABORATORY TESTING: EVOLVING INTO THE 21ST CENTURY SERIES

Blood Gases and Other Critical Care Analytes

Weighing All the Options When Selecting New Instrumentation

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During the past several decades, pH/blood gas and electrolyte measurements have been among the primary STAT analytes needed to assess the status of critically ill patients. Recent reports have suggested *(1–8)* that the addition of other analytes to blood gas systems would be advantageous. For example, technology advances have made it possible to include lactate, glucose, and other analytes on the same analytical instruments that perform blood gases. Unfortunately, the issues surrounding this area of laboratory testing are easily blurred in a maelstrom of competing marketing claims. Furthermore, technological feasibility does not necessarily equate with clinical need.

As clinicians become increasingly aware of new STAT testing technologies and begin to demand quicker turnaround of more and more analytes, many hospital laboratories have turned to faster pneumatic tube systems for sample transport and dedicated analyzers for use in the near-patient testing environment. However, it is the laboratorian that must weigh all the options—analytical, financial, and operational—when selecting analytical instruments that incorporate new critical care analytes.

Hospital administrators expect clinical laboratory scientists to make these decisions based on resources, staffing, reliability of systems, cost, and clinical and operational measures of outcome. While clearly there is a clinical need for certain critical analytes, careful analysis of the logistics and cost issues for these analytes must include numerous details to provide a true picture of overall cost/benefit. Additionally, each group involved in the selection process—the laboratory, management, finance, and direct caregivers—has a different perspective, each of which is legitimate in its own right.

The laboratorian's job is to deliver analytically accurate test results that meet the needs of patients and clinicians. In order to accomplish this, clinical laboratorians must consider the range of available instrumentation, as well as its analytical and operational reliability. In addition, test frequency, sample collection requirements, and the economics of care, including reimbursement policies and budget allowances, must all be considered. This article reviews some of the factors that laboratorians should take into account when deciding whether to include additional analytes on near-patient test systems that also measure blood gases.

What is a Critical Analyte?

In management of clinical laboratory testing, the word "critical" connotes clinical importance and short turnaround time. However, different institutions have different, and sometimes seemingly arbitrary, definitions of what "critical" means.

More than a decade ago, AACC's Quality Assurance Committee recognized the need for a more principled approach to these sometimes-contentious issues and developed a set of guidelines for providing quality STAT laboratory services *(9)*. Although the STAT test list included in the AACC publication needs updating in the light of new analytical and therapeutic approaches that have evolved, the principles behind that list remain valid *(Table 1)*. The use of these criteria, combined with information about the institution's typical patient population and therapeutic possibilities, can be very useful in deciding which analytes should be classified as urgent and important.

In today's reimbursement and regulatory environment, a new third category called "Responsible and Responsive," may also be needed. This category would take into account the strict clinical requirements noted in the original AACC guidelines, and it adds two new perspectives: laboratory management in today's health care environment and analytical capabilities of new instruments. In addition, third-party payers may find this new category useful for determining reimbursement policies. In critical care situations, legitimate physician orders and ordering patterns may not always fit the predetermined criteria developed by insurers who have little understanding of critical care analyses.

Table 1. Principles of Test Categorization*

AACC Test Category 1: Urgent

- Analyte is a cause or effect marker for immediate life-threatening condition.
- Specific and immediate therapeutic action is based on analyte level.
- Timeliness and reliability are crucial.

AACC Test Category 2: Important

- Analyte levels are necessary for diagnosis, triage, follow-on therapy.
- Timeliness is a key factor.

Suggested New Test Category: Responsible and Responsive

- The quantities are considered clinically related.
- The frequency of need for one quantity is nearly "simultaneous" with others.
- A single blood specimen is required using analytically related or compatible technology.
- The cost of treatment vs. no treatment vs. total costs based on the test is significant and related to the test performed.
- Timeliness is significant, but not critical.

**Modified from AACC Guidelines* (9)

Using the Fundamentals

Homeostasis, the dynamic balance between opposing systems or within synergistic systems, is a characteristic that can be applied to a number of areas in human physiology, including hematopoiesis, hemostasis, and acid-base/bioenergetic balance. While the individual characteristics of each of these systems can reach a critical state and thus deserve urgent attention by testing facilities, there are three systems that stand out as fundamental homeostatic systems: acid-base, blood gases, and electrolytes as well as the determinants, mediators, and substrates of those systems.

Using the AACC criteria for defining urgent testing, an updated list of urgent tests would contain a combination of analytes from the original AACC list along with new analytes that also fit the criteria *(Table 2)*.

As markers of fundamental homeostatic mechanisms, the classic blood gas measurements—PCO_2 and PO_2—have been and clearly remain the best laboratory-based test profile for assessing acid–base status and gas exchange in hemodynamically stable patients. The measured blood gas quantities and their derivatives (e.g., base excess) provide the basis for acid–base balance and oxygenation status, but overlook some physiologically key elements such as the actual amount of oxygen being transported and used. In some situations, the lack of this information can impact clinical decision-making.

Measurement of pH or hydrogen ion concentration (cH^+) provides a current assessment of acid–base level, but does not give an indication of the cause. The additional measurement of carbon dioxide tension of arterial blood, PCO_2(aB) provides an ability to assess the extent of the respiratory or ventilatory component of any acid–base disorder.

However, when these analyte quantities are combined with base excess of blood [BE(aB)] and/or base excess of extra cellular fluid [BE(ecf)], an assessment of the non-respiratory component of any acid-base disturbance can be calculated. There is a long-standing controversy among the experts regarding which BE value to use. BE(aB) is by far the most commonly used and in fact could be measured directly. On the other hand, BE(ecf) is more representative of long-term clinical conditions, but cannot be measured. An algorithm based on a standard model of extra-cellular fluid must be used to calculate BE(ecf). The reference values for both BE quantities are the same, and in clinical conditions they both change in the same direction—the only difference is in the amount of change

Table 2. STAT Testing 2000—An Updated List of Urgent Analytes

Traditional Urgent Blood Analytes*

- Blood Gases : PO_2, PCO_2
- Hydrogen Ion Concentration: pH (cH+)
- Hemoglobin: Hb or Hct/Packed Cell Volume (PCV)
- Electrolytes: Na^+, K^+, Ionized Ca^{++}
- Glucose
- Prothrombin (PT)
- Partial Thromboplastin (PTT)
- Platelets

New Urgent Blood Analytes

- Base Excess of Blood (BE) or of Extra-cellular Fluid/Bicarbonate
- Activated Clotting Time (ACT)

**Based on AACC Criteria* (9)

The basic blood gas panel includes the most important indicator of oxygenation status for many patients: the oxygen tension of arterial blood [PO_2(aB)]. Molecular oxygen—O_2—is present in the air we breathe, and it is this form of oxygen in combination with products of glucose metabolism that fuels cellular mitochondria to manufacture the bioenergy storage compound adenosine triphosphate (ATP).

Other aspects of oxygenation—oxygen transport, uptake, and utilization—mandate measurement of total hemoglobin, oxygen content, and saturation. Also, many clinical situations can justify inclusion of hemoglobin derivatives such as carboxyhemoglobin along with the blood gas determinations.

The addition of potassium to the basic set of measurements is most appropriate in the critical care setting, considering potassium's effect on cardiac efficiency and output. In critically ill patients, parenteral therapy that involves electrolytes also supports the addition of other electrolytes such as sodium and chloride, which are frequently needed in the same time frame as the blood gases. Ionized calcium may be required in the critical care setting as well, albeit in somewhat more restricted clinical conditions than those that justify sodium and potassium. For example, in patients receiving massive transfusions of citrated blood, calcium is chelated by the citrate, causing significant lowering of the ionized calcium level. The resulting cardiac and neuromuscular effects can have profound impact on patient morbidity.

There is a well-documented need for monitoring sodium and chloride during parenteral therapy and the analytical compatibility of the electrolytes makes the measurement of all electrolytes, along with the blood gases, an operationally and clinically prudent course of action in a wide range of clinical testing environments.

Which Tests Should Be Considered Important?

Taking into account current analytical technologies and therapies, a new list of analytes based on the criteria for AACC test category 2 might contain the additional determinations listed in *Table 3*. For example, new measurement technologies, such as direct "whole blood" lactate or ionized magnesium using ion-selective electrodes (ISEs), make it possible to readily obtain quantitative information on these analytes that was not feasible in the past. Similarly, significant new therapeutic intervention for heart attack patients warrants the addition of CK-MB and the cardiac troponins I and T to this list.

Unfortunately, the remaining analytes on the list of important blood analytes do not pass the test for clinical, analytical, and operational compatibility with the other analytes on either the urgent or important lists. Current technology for measuring them is not readily compatible with the technology for the other analytes. Other analytes such as ionized magnesium, which are analytically feasible and available on some STAT analyzers, may need to be reconsidered for appropriateness in the future.

Making the Choices

In order to make the best choices when selecting urgent care instrumentation, laboratorians need to seek the expertise of a multidisciplinary group: clinicians, scientists, engineers, and marketing staff, as well as economic and regulatory experts. The availability of multiple analytes on the same analytical system certainly provides some real operational and even clinical advantages, but at the same time may require re-education on issues such as sample processing, costs, availability of the measurements, and billing practices. *Table 4* presents some important points to consider when making this decision. Overall, it is important to look at the clinical and operational compatibility of the timing and urgency related test groups when making a decision on the purchase of new critical care instrumentation.

Table 3. Important Blood Analytes*

- All analytes from the Urgent AACC Category 1 list
- Urea, Creatinine, Fe, NH_4 , Bilirubin, Ketones, ALT, AST, Amylase, HCG,
- Leukocytes, Differential, Fibrinogen

New Important Blood Analytes

- Oxygen Saturation and Content
- COHb, MetHb
- Lactate
- CK-MB, Troponins T and I

**Based on AACC Test Category 2* (9)

Even considering all of these factors, there are a number of commercially available instruments that meet the clinical and operational requirements for urgent, important, and responsible testing. Most of these systems allow for flexibility based on the needs of a care unit's patient population and specialties, although some systems are more flexible than others.

Another important consideration when deciding on a STAT test menu is what the Health Care Financing Administration (HCFA) allows in terms of test profiles. Laboratorians must consider that the operational convenience of any device may be limited by government regulation. Without the availability of inclusive profiles on a patient-to-patient basis, adding STAT analytes to the test menu could push the limits of operational and economic responsibility, especially when considering some of the third-party reimbursement criteria enforced by HCFA's Office of the Inspector General.

Making It Work

The laboratory testing paradigm continues to shift as clinicians' needs for faster turnaround time increases, as acceptable sample sizes get smaller, and as technology takes some of the art and science from laboratory measurement and makes it possible to move it outside the laboratory. How are the seemingly incompatible demands of highest accuracy in patient testing reconciled with requirements that seem to push accuracy in the opposite direction? How should laboratorians and clinicians reconcile quality patient care with economic and the requirements of the authorities that pay for the care? These are difficult questions to answer, but if we remain aware of the basic issues, we can better assess individual situations and arrive at workable solutions.

Table 4. Points to Consider When Selecting New Critical Care Analytical Systems

- Similar ordering situations and frequency of ordering
- Compatible degree of urgency
- Usually "simultaneous" need for profile elements
- Critical or critical and important analytes
- NOT routine/experimental
- Compatible sample handling and anticoagulants
- Measurement technology
- Compatible maintenance intervals
- Sensor life
- Reagents
- Calibration and calibrators
- Appropriate levels of analytes measured
- Matching reference methods

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