

The Laboratory in the Operating Area

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DELAY in delivering the benefits of the latest scientific advances to the bedside has been recognized by many. The use of newer laboratory procedures such as blood-gas analysis is acknowledged to permit more accurate diagnosis and specific treatment. Yet the difficulties encountered in obtaining frequent rapid and accurate measurements of blood gases have often prevented large-scale use of this essential means of patient care. It is with this problem in mind—the delivery of optimal medical care to the surgical patient and the acutely ill—that clinical laboratories are being instituted in operating areas and intensive care units. The Department of Anesthesia at the University of Pennsylvania launched such a laboratory a little over three years ago; its utilization is reviewed in this report.

Capabilities

A Department of Anesthesia clinical laboratory can aid in patient care by supplying the following services:

RAPID, ACCURATE ANALYSIS OF BLOOD GASES

We have attempted to make blood-gas analysis convenient for the clinician by having available sterile heparinized syringes, plastic buckets so that the sample may be carried to the laboratory in ice water, and rubber stoppers into which the needle may be plunged for anaerobic storage of the sample. To minimize leakage of blood after arterial puncture, we have encouraged the use of 23-gauge needles and the application of pressure for five minutes after the needle is withdrawn.

The physician who draws a blood sample must fill in the upper left (dark area) of an information sheet (fig. 1). Patient identification data are required, along with information about the clinical history and the reason for

the analysis. In addition, it is vital to know the percentage of inspired oxygen; otherwise the arterial P_{O_2} cannot be interpreted reasonably. Therefore, Pauling paramagnetic oxygen analyzers are made available from the clinical laboratory. The minute ventilation (\dot{V}_E) must be known as well, for proper interpretation of the arterial P_{CO_2} ; to this end flowmeters such as the Wright anemometer are kept available in the clinical laboratory. The upper right-hand part of the blood-gas data sheet (fig. 1) is used by the laboratory technician to record data. The raw reading is corrected for electrode drift, any metabolic change which may have occurred during the delay between taking the sample and making the measurement, and the temperature difference between the patient and the electrode. An electrode factor of 1.04 is used for the P_{O_2} measurement to correct for errors introduced by calibrating with gases when measuring blood P_{O_2} . While it is not essential that all of these corrections be made in all clinical situations, they add minimally to the time necessary for the measurement, and they serve a valuable teaching function, when the reasons for making these corrections become known to those who deal with blood-gas measurement. Thus their understanding of the equipment and the technique is increased. A slide-rule calculator is used to compute base excess, which is reported along with the blood-gas results. Oxygen saturation (reflectance oximeter) and hematocrit (micro or Wintrobe) may be measured when indicated.

The lower third of the blood-gas sheet is used by the technician to return the results to the physician who requested them. These results are then affixed to the patient's chart. The upper part is filed in a loose-leaf book kept in the laboratory. From these accumulated data sheets we are able to extract information about utilization of the laboratory.

AVAILABILITY OF MONITORING DEVICES

The following devices, which constitute a minimum collection of useful measuring tools

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UNIVERSITY of PENNSYLVANIA
Department of Anesthesiology Clinical Laboratory
BLOOD GASES

Name FITTS HUP# Room S-100 Date 12 March '67
Service FITTS Room S-100 P_{aw} 720.5 P_a 72.4 P_{co} 7.374
Age 42 Sex M Ht. 69" Wt. 145
Anesthesiologist LEVITT / PAUCA
Sample Site (D) RADIAL ARTERY
Time Drawn 10:00 am
Body Temp. 36.6°C
Elect. Temp. 36.6
Reference 5.1.5 47.4 7.374
Aliquot 1 6.4.0 35.5 7.374
Aliquot 2 6.6.0 34.5 7.374
Mean Value 6.5.1 35.0 7.374
Reference 5.1.5 47.4 7.374
Rel. Drift 0.0 0.0 0.0
Blood Value (corr. for drift) 6.4.7 35.0 7.370
Elect. Fac. 5.1.5 X X
(x 1.04)
Time Measured 10:00 am
Met. Corr. 6.7.7 35.0 7.374
Temp. Corr. 6.5.7 35.0 7.371

CLINICAL HISTORY
Intermittent Fever
Hepatic Abscess
Periparturient Gouty
Dorsal Ulcers

REASON FOR INVEST.
Anaesthetic
Assessment of ventilation

DETAILS OF RESPIRATION
Spontaneous Controlled Mask Tracheostomy
Assisted Controlled Mask Tracheostomy
Anes. N₂O - 60% O₂ - 40% Del. Conc. 68%
% Inspired O₂ 22%
% 9.0 6.0 min
Resp. Rate 9/min

WHOLE BLOOD RESULTS
P_a (mmHg) 65.7 P_{co} (mmHg) 33.3 pH 7.381
Calc. Base Excess (mEq/L ECF) -4.0
% Sat. (calc.) 92.5%
HCT. —
HB. (gm%) —
(O.D. —)

UNIVERSITY of PENNSYLVANIA
Department of Anesthesiology Clinical Laboratory
BLOOD GASES

Name FITTS HUP# Room S-100 Date 12 March '67
Service FITTS Room S-100 P_a (mmHg) 65.7 HB. (gm%) —
Anesthesiologist LEVITT / PAUCA P_{co} (mmHg) 33.3 HCT. —
Sample Site (D) RADIAL ARTERY pH 7.381 % Sat. 92.5% (calc.)
Time Drawn 10:00 am Calc. Base Excess (mEq/L ECF) -4.0
DETAILS OF RESPIRATION
Spontaneous Controlled Mask Tracheostomy
Assisted Controlled Mask Tracheostomy
Anes. N₂O - 60% O₂ - 40% Del. Conc. 68%
% Inspired O₂ 22%
% 9.0 6.0 min
Resp. Rate 9/min

COMMENTS
Still on the sample of
body line oxygen - tracing
No O₂ has been added since
his 2nd arterial blood gas
patient H.W.

FIG. 1. Data sheet for blood-gas determination. The physician who draws the sample must fill in the information required in the upper left portion of the sheet. The work sheet for the laboratory technician is the upper right portion. Results are recorded on the detachable lower third of the sheet, and affixed to the patient's hospital record. The upper two-thirds is retained by the laboratory and filed in a loose-leaf binder.

for the clinician, can be borrowed from the clinical laboratory.

Gas Flowmeters (Dräger Respirometer, Wright Anemometer). These may be attached to the anesthesia machine with adapters, for measurement of the minute ventilation during either controlled or spontaneous breathing. They may be attached to automatic ventilators, or used with a face mask or endotracheal

tube. They have found use in the operating area, the recovery room, in intensive care units, and on the wards. The importance of knowing the expired ventilation when PaCO₂ is measured cannot be overemphasized. How could one detect a large and unexpected dead-space without both measurements?

Pauling Paramagnetic Oxygen Analyzer. A knowledge of inspired oxygen tension is neces-

sary if one is to interpret intelligently arterial P_{O_2} measurements. Only when both inspired and arterial P_{O_2} are known can one assess the efficiency of pulmonary oxygen transfer, or inadequacy in the presence of atelectasis, shunting, or maldistribution of ventilation and perfusion. The oxygen analyzer also permits measurement of inspired oxygen concentration in nitrous oxide-oxygen anesthesia, making the technique safe and practical. The sampling line can be inserted into the conductive rubber tubes of an anesthetic circle system, utilizing a 23-gauge needle, with minimal damage to the tubes. The device also has been used to sample the inspired atmosphere in oxygen tents, with some startling discoveries made when the tents were not carefully sealed.

Mixed Venous Carbon Dioxide Measurement. A bag and mask with attached stopcocks for gas sampling permit measurement of mixed venous P_{CO_2} by the rebreathing technique.¹ The P_{CO_2} of the sampled gas contained in the bag may be measured in the blood-gas electrodes or with an infrared carbon dioxide analyzer. Thus, arterial P_{CO_2} can be estimated without sampling of blood, by assuming a gradient of 7 torr from mixed venous to arterial blood.

Explosimeter.* This device may be used to test the explosiveness of operating area atmospheres, or of expired gas. It can be employed profitably when a switch from explosive to nonexplosive anesthesia must be made, for instance in order to permit use of electrocautery. It is also a useful teaching device when one wishes to demonstrate the areas of hazard during administration of explosive agents.

Additional Devices. The availability of a force transducer and oscilloscope for monitoring intra-arterial blood pressure in the desperately ill is a necessity. We have found it convenient to stock several different types and sizes of plastic catheters for arterial puncture, and plastic stopcocks for use when blood pressure is to be monitored.

The inspiratory force meter is another monitoring aid, whose use to test for residual curarization or postanesthetic muscle weakness has been amply justified.²

The Block-Aid Monitor or other nerve stimulator is yet another well-known piece of equip-

ment which can yield useful information on the degree and character of neuromuscular blockade during and after anesthesia.³

GAS CHROMATOGRAPHY

The gas chromatograph has proven useful for measurement of concentrations of general anesthetics in gas or blood samples. Measurement of anesthetic concentration in inspired gas provides a means of checking on the function of flowmeters and vaporizers, also providing an interesting way of correlating laboratory measurements with depth of anesthesia. Furthermore, the comparison of inspired with mixed-expired concentration permits judgment of the degree of whole-body equilibrium attained with an inhalation anesthetic; it has proven useful in teaching gas uptake to residents. Gas samples are drawn into 50-ml individually-ground glass syringes through 23-gauge needles inserted through the inspiratory and expiratory tubings of the anesthetic circle system. Measurement of anesthetic concentrations in blood is considerably more difficult.⁴ The answer is not rapidly available and the blood concentration usually yields little more useful clinical information than can be deduced from the inspired and mixed-expired concentrations.

ADDITIONAL MEASUREMENTS

Measurements of blood and urine electrolytes and osmolality can be obtained relatively rapidly from the central laboratories of the hospital. However, syndromes such as water intoxication, inappropriate secretion of antidiuretic hormone, dehydration, and high- and low-output renal failure are being recognized with increasing frequency in the operating room and in postoperative and acutely ill patients. Therefore, it has proven convenient to have facilities in the Department of Anesthesia clinical laboratory for electrolyte and osmolality determinations. A flame photometer, a chloridometer, and an osmometer, therefore, are parts of this laboratory's armamentarium. Special forms similar to those for blood-gas determinations must be filled out for these measurements as well.

Additional special tests include a titration method which permits precise determination of the amount of protamine required to reverse a dose of heparin, as required following

* Mine Safety Appliances Company.

UTILIZATION OF CLINICAL LABORATORY

Number of Blood Gas Determinations per Month

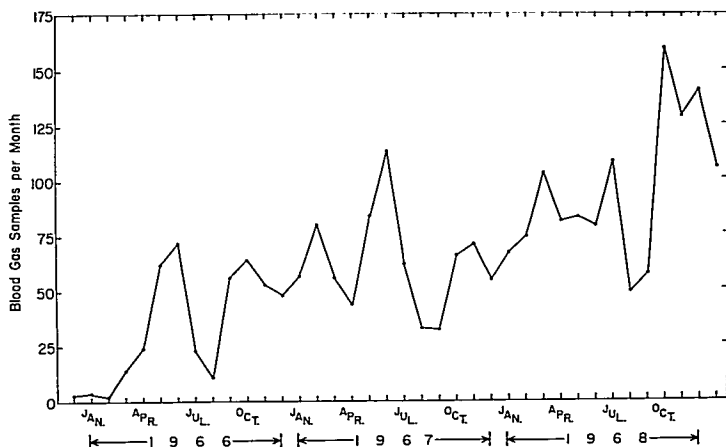


FIG. 2. Utilization of the clinical laboratory. The number of blood-gas determinations per month is plotted over a 38-month period. The general trend toward increased utilization is obvious. The major dips occur during the summer months when the caseload in the operating area is small.

termination of cardiopulmonary bypass. The test is done by preparing a series of test tubes with varying amounts of protamine, to each of which is added a fixed quantity of the patient's blood. By noting in which tube a clot first appears, one determines the minimum amount of protamine which will neutralize the heparin contained in the blood sample. Consideration of the patient's blood volume then permits calculation of the proper dose of protamine given the patient.⁵

Organization

A staff of two technicians trained both on the job and in commercially available courses is on hand to permit full daytime coverage (8 AM to 5 PM). The part-time services of a dishwasher are required to keep glassware clean and ready for use. A knowledgeable staff supervisor is essential. It is this person who provides consultation to the technicians when problems appear, who makes policy decisions, and on whom the over-all responsibility of the laboratory falls.

Often large numbers of measurements must be made rapidly to be of real clinical use; therefore, it is essential that the equipment be in good repair at all times. The technicians test the equipment each morning, insuring acceptable operating condition. They are responsible for stocking replacement parts, calling for technical repair service when needed, and seeking additional help when necessary from the physician who supervises the laboratory.

If residents and staff are taught to use the blood-gas electrode system, they are able to make the measurements that they require at night and on weekends. To this end we have permitted many of our residents one month of their training period in the clinical laboratory. They become familiar with the machines and their problems, with methods of laboratory measurements, and with the types of problems that require the support of such a laboratory. In addition the resident assigned to the clinical laboratory may be called to aid in another area of the hospital in the management of res-

piratory problems. In the case of such a consultation he becomes not only the physician at the bedside but also the scientist in the laboratory, personally making the clinically important measurements for the patient. Thus, the clinical laboratory can serve an important teaching function both within and outside the Department of Anesthesia.

In addition, the clinical laboratory is able to offer support for certain clinical research projects, such as the investigation of new anesthetic drugs. The presence of a mechanical calculator in the laboratory makes it possible for the technician who makes the measurements to do the data processing and statistical analyses and present the finished results to the physician supervising the study.

Utilization

The measurements most commonly requested are those of blood gases—arterial P_{O_2} , P_{CO_2} , and pH. The steady growth in the number of blood-gas determinations per month is indicated in figure 2. We do not believe that there are more patients requiring blood-gas measurement now than there were in the early months of the laboratory's organization. Rather, we believe that education within our department, and outside as well, has contributed to understanding of the clinical value of making these measurements.

The most common reasons cited for requesting blood-gas determinations center around the question of effective ventilation and levels of arterial P_{CO_2} ; 51 per cent of the requests fall into this category. The second major reason for blood-gas analysis is the matter of pulmonary function and oxygenation of the blood. These P_{O_2} -related problems account for 32 per cent of requests. Other less common reasons include determination of the degree of metabolic acidosis, preanesthetic evaluation of pulmonary function, and sampling from the heart-lung machine during cardiopulmonary bypass to evaluate oxygenator function.

Analysis of requests by type of patient indicates that 44 per cent of blood-gas samples are drawn during anesthesia, one third of these during cardiopulmonary bypass. Forty-two per cent of samples are taken in the immediate postoperative period, with one third of these coming from open-heart patients. Fourteen per cent of samples come from patients on the

medical and surgical wards, for a variety of reasons, including respiratory problems, preanesthetic baseline studies, and long-term, postanesthetic follow-ups.

The use of gas chromatography to measure anesthetic concentrations has been less common than the measurement of blood gases; but this use, too, has grown. There were 86 samples in 1966, 120 in 1967, and 533 in 1968. Blood electrolytes and osmolalities are required less frequently; only 16 such samples were submitted in 1966. Thirty-nine of these determinations were performed in 1967, and 131 in 1968.

In the 38 months that this laboratory has been functioning many medical students have been assigned to it in rotation, and 20 residents have served one-month rotations here. Several junior staff men and two visiting professors worked in the clinical laboratory for periods from a week to a month at their own request. We believe that all of these men now have a somewhat different outlook on the problems of laboratory measurement. They are able to do the determinations themselves, enabling them to manage certain problems at night and on weekends. Finally, we hope that the affiliates are teaching the mechanism and value of these methods to others.

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