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INSTRUMENTATION FOR BEDSIDE INFORMATION - PROGRESS AND CHALLENGES

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Abstract - A brief history of bedside testing is presented. Analytes which can readily be studied at the bedside are identified and the instruments which may be used are briefly described. The advantages and limitations of bedside measurements are discussed. An attempt is made to anticipate the future potencialities and challenges of this aspect of clinical laboratory science.

INTRODUCTION

Clinical laboratory practice has had an explosive growth within the past two decades. One of the trends that has evolved within this dramatic expansion is the evolution of instruments which can be used at the bedside. As with any other change in health delivery practice, one finds ardent supporters of the trend and others who speak in a negative manner or with great reservation. Bedside situations range from an intensive care unit in an American hospital to a primitive bedside in a dwelling in the rural part of India. I will consider all types and will not confine my attention to sophisticated hospitals nor only to rural bedsides in developing countries. The objective in all situations involves obtaining information.

HISTORICAL BACKGROUND OF BEDSIDE TESTING

Hospitals have not always had clinical laboratories. In fact it is only within the past 50 years that a clinical laboratory has been regarded as a critical component of a hospital. Prior to the time laboratories were part of hospitals, there was actually very little laboratory study of any sort. However much of the testing that was done occurred at the bedside. Hydrometers were used to measure the specific gravity of urine. Several well designed instruments were created for measuring hemoglobin concentration of blood. The Haden-Hauser Hemoglobinometer is an example of such an instrument which was designed and used quite widely in the USA about 50 years ago. The microscope is an instrument or device which received significant attention for bedside testing. This is emphasized by the fact that many paintings depicting the diagnosis and treatment of disease in the 19th century had a group of individuals at the bedside with one of them intently using a microscope. The tests that were done at the bedside involved the recognition of bacteria in urine, identification of casts and cells in the urine, recognition of bacteria in spinal fluid, and evaluation of the number and characteristics of the erythrocytes and the leucocytes in the blood.

The very first clinical chemistry laboratory in the USA was initiated at the New York Postgraduate Hospital during the second decade of the present century. Victor C. Myers, with a recent Ph.D. in Biochemistry from Yale University, was in charge of the laboratory. I have had an opportunity to hear first hand about this laboratory since I was later a graduate student of Dr. Myers. Blood sugar, urea, creatinine, chloride and uric acid were the principal measurements made in this early laboratory. However, the initiation of hospital laboratories tended to discourage bedside testing.

I had an opportunity to work for a Clinical Laboratory for one summer slightly less than 50 years ago. This laboratory which was part of a large university medical school served a medical center with approximately 600 beds and a large outpatient population. DuBosc type colorimeters were used since at that time there were no spectrophotometers or "photoelectric colorimeters". There was a Van Slyke instrument for measuring CO_2 capacity. There were no pH meters or glass electrodes, no flame photometers, no chromatography or electrophoresis. Amylase and alkaline phosphatase were the only enzymes measured. Three other persons and myself did all of the analyses and also washed all of the glassware. There was no stat service and no night service. The laboratory functioned for 5-1/2 days per week, but on Sunday the lab was closed. At that time there was essentially no bedside testing that I was aware of.

During the period between 1920 and 1950 there was a continuing growth of clinical laboratories, but the interest and usage of bedside tests declined. The feeling prevailed that the clinical laboratory could create all of the information required for correct diagnosis and good patient care.

Within the past two decades there has been a great increase in all types of clinical laboratory instrumentation. Within this complex array, there has appeared a small component of instruments and systems which are specifically designed or are adaptable to bedside testing.

ANALYTES, INSTRUMENTS AND INFORMATION - CURRENT STATUS

Within the past decade there has been a literal explosion of procedures and instrument technology relating to the clinical laboratory. This same dramatic change has not occurred with regard to the number of analytes which are widely studied although the number is growing. Instrumentation and automation which has been designed to function at the bedside or is applicable to bedside application is a small but interesting component of the explosive growth of clinical laboratory technology.

I propose to describe the current status of bedside testing involving automation and instrumentation. It is not practical to review every procedure and every instrument but examples of many will be mentioned. The basis for paragraph separation is primarily with respect to analytes but this is not practical in all cases. Methods are identified with regard to the type of specimen by indications of WB for whole blood, S for serum, P for plasma, TC for transcutaneous, B for breath, U for urine and T for tissue. The various components of bedside laboratory study include clinical chemistry, toxicology, hematology, microbiology and immunology.

Blood Volume (WB)

Blood volume may readily be measured at the bedside by the intravenous injection of a measured quantity of ^{125}I labelled human serum albumin. After a few minutes to allow for mixing, a specimen of blood is removed and the amount of dilution of the isotopically labelled albumin measured. This measurement is made rapid, convenient and accurate by the use of a programmed instrument which automatically counts the radioactivity of the albumin prior to injection and of the blood following dilution in the circulating system. From these values the instrument gives a direct readout in terms of liters of blood volume. One example of such an instrument is the Volemetron®. Blood volume measurements are useful in cases of severe burns.

Serum Ketone (S/P)

Ketone bodies occur in the serum in readily measurable amounts in diabetic ketoacidosis. The changes in serum ketone levels have been used as a bedside monitoring test in the treatment of diabetic coma. One easy-to-use method for measuring serum ketone is to moisten the reagent area of a Ketostix® with a small quantity of serum and then read the color 15 seconds later. Values are obtained by comparison with a color chart. Alternatively the ketone area of Multistix® or N-Multistix® can be used and the reading made with the instrument, Clini-Tek® .

Glucose (WB)

Distortions in blood sugar which occur in diabetes may involve either elevations above the normal range (hyperglycemia) or decreases below the normal range (hypoglycemia). Measurement of blood sugar on small specimens of whole blood obtained by skin puncture is a bedside test. One system for such measurement is Dextrostix®/Glucometer®. This involves a reagent strip on to which a large drop of blood is placed. After exactly one minute, the blood is washed off and the strip is inserted into a small reflectance measuring instrument. A direct reading of the color is translated into a value for blood sugar which appears on the lighted panel of the instrument in digital readout form. Fig. 1 is a photograph of a Glucometer.

Hemoglobin (WB)

Measurements of the hemoglobin content of blood at the bedside originated several centuries ago when physicians looked at a specimen of blood from a patient and decided from the color of the blood that the blood was too thick or too thin. These judgements of color were indications of the amount of hemoglobin. Subsequently, instruments based on visual color comparisons appeared and these were to a significant degree used at the bedside. It was not until the appearance of clinical laboratories in hospitals that hemoglobin measurement at the bedside diminished due to the measurements being moved to the clinical laboratory. Quite recently easy-to-use instruments have reappeared at the bedside. These include sophisticated instruments such as the Hemoximeter® which automatically measures and displays the result for hemoglobin as well as the oxygen saturation of the hemoglobin. Relatively small portable compact, battery-operated colorimetric instruments specifically provided with unitized reagents are also available. An example of the latter is the Compur™ mini-colorimeter which is

shown in Fig. 2.

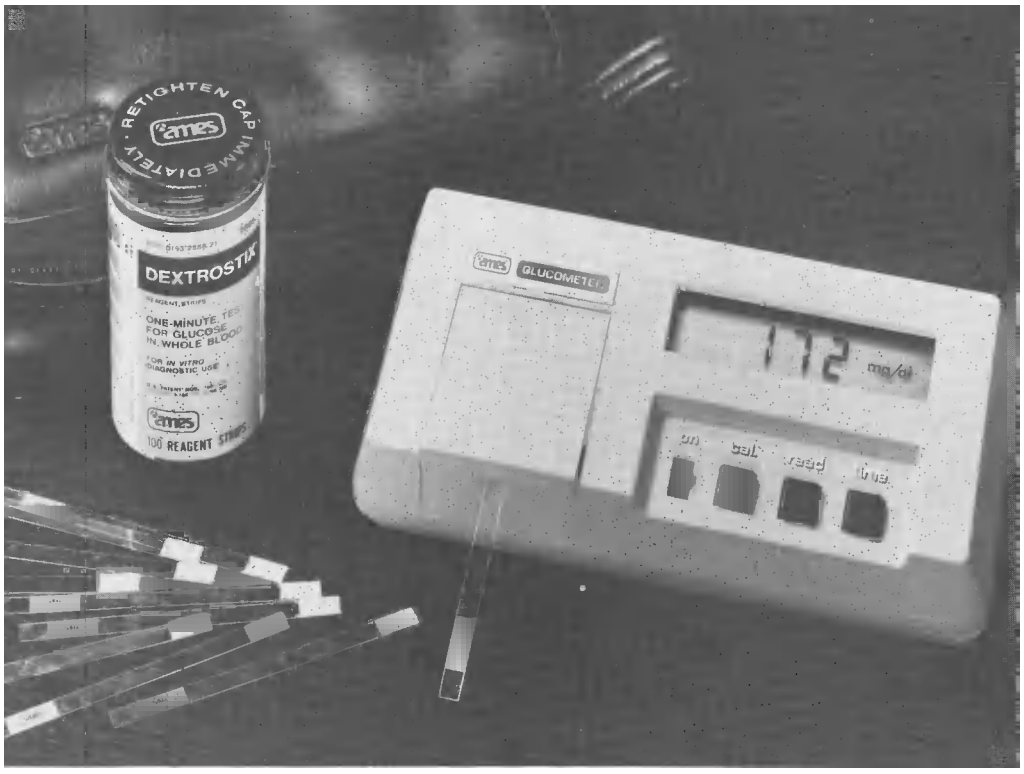

Fig. 1 Dextrostix/Glucometer for measuring whole blood glucose

Hemoglobin (S/P)
Hemoglobin in serum or plasma is indicative of a hemolytic condition. Hemolysis occurs in many disorders ranging from transfusion reactions due to mismatch of blood to sickle cell thalassemia and nocturnal paroxysmal hemoglobinuria. Bedside examination is particularly important when massive intravascular hemolysis is suspected. If the hemolysis is massive, no chemical or instrumental test is required once the serum has been obtained since the serum will have a bright red color. The most useful instrument in such cases is a bedside centrifuge such as the Compur mini-centrifuge shown in Fig. 3.

Oxygen Saturation (TC)
The measurement of oxygen saturation of hemoglobin can be performed at the bedside with an instrument which automatically measures oxyhemoglobin and reduced hemoglobin in a 25 µl specimen of blood. The instrument automatically displays a result for oxygen saturation as percentage along with a value for total hemoglobin. Such measurements are particularly useful in differentiating respiratory abnormalities especially when studied during resting, following exercise and following the breathing of high oxygen mixtures. An example of an instrument for measuring oxygen saturation is the Hemoximeter® which is shown in Fig. 4. Continuous monitoring of oxygen tension by a transcutaneous oxygen electrode can be carried out with a non-invasive transcutaneous blood gas system. A chart recording of the P_{O_2} can be established. A photograph of this instrument which also contains a P_{CO_2} monitor is shown in Fig. 5.

Hematocrit (WB)
The hematocrit is a value which indicates the relative volume occupied by packed red cells following centrifugation of whole blood. Hematocrits are frequently used to provide an estimate of the hemoglobin of whole blood. When coupled with red blood cell counts, more sophisticated parameters relating to erythrocytes can be established. Bedside measurement of hematocrit is made practical with miniature hand-held centrifuges which are designed to measure hematocrit. Such an instrument is shown in Fig. 3.

Carbon Dioxide Monitor (TC)
Carbon dioxide plays an important role in the acid-base and respiratory equilibrium of the body. Bicarbonate measurements and measures of carbon dioxide partial pressure in arterial blood are not ordinarily done at the bedside. In situations involving continuous monitoring

of carbon dioxide, a transcutaneous P_{CO_2} electrode can provide a reliable continuous reflection of the patient's carbon dioxide status. The electrode is attached to the patient's skin and to the monitoring instrument which has a display for P_{CO_2}. The instrument can also be connected to a continuous pen recorder for a permanent record. A picture of this instrument is shown in Fig. 5. Carbon dioxide monitoring is important in respiratory disorders and also provides critical information in disorders of the acid-base equilibrium.

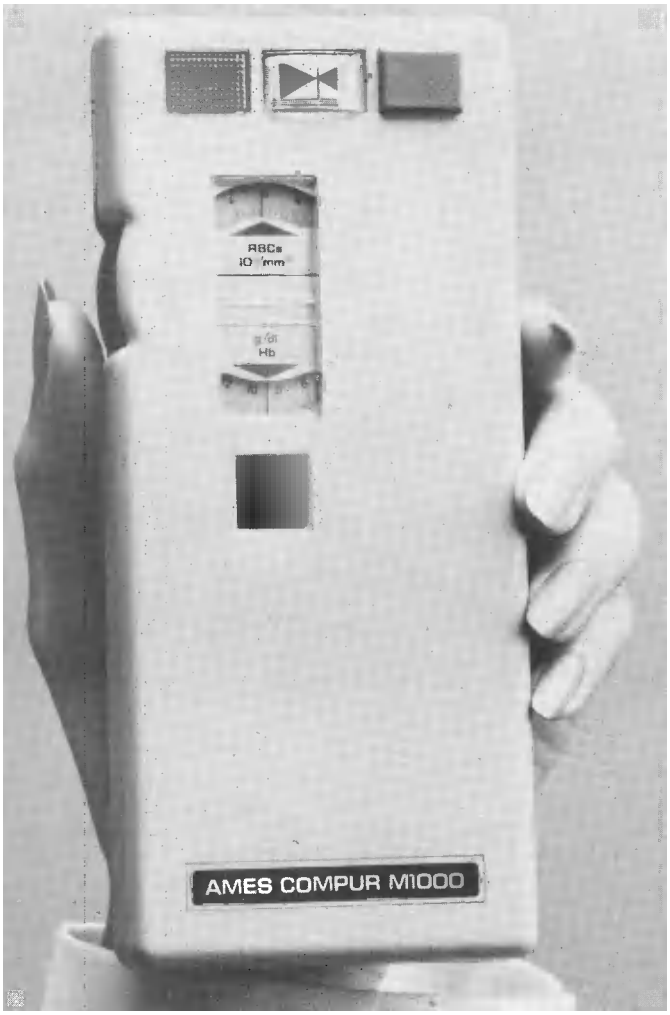

Fig. 2 Compur, a portable battery-operated mini-colorimeter for measurement of hemoglobin.

pH (S/P)

pH is a critical component of blood gas-electrolyte measurements. Such studies are requisite for the diagnosis and monitoring of treatment of disorders of the acid-base equilibrium involving both acidosis and alkalosis. The electrode for measuring pH is incorporated into a variety of pH/blood gas analyzers which may be used at the bedside or in the side-room laboratory of an intensive care unit.

Continuous Blood Glucose Monitoring With Computer Response

Patients with insulin-dependent diabetes are extremely difficult to regulate during surgery and in the course of other acute medical episodes. The Biostator® shown in Fig. 6 is an instrument which is designed to regulate blood sugar of diabetic patients during acute illness and during surgery. A sensor is placed in the vein of the patient and this unit provides a continuous measurement of blood sugar. The values are entered into a small microprocessor which controls an infusion system for insulin solution and an infusion system for glucose solution. When blood sugar falls below a specific identified level, the microprocessor activates intravenous injection of glucose. When the blood sugar rises above an identified level, the microprocessor activates injection of insulin. Impressive results in improving

the course of insulin-dependent diabetics during surgery and during acute illness have been obtained due to the regulating effect of the Biostator.

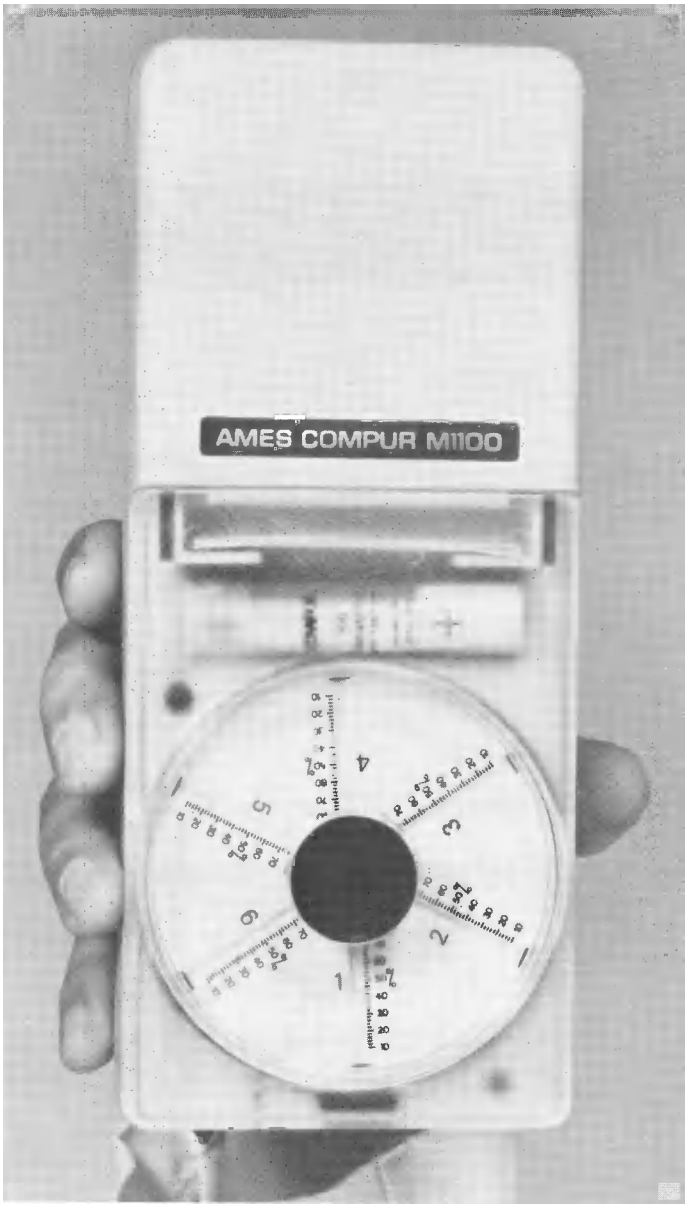

Fig. 3 Compur, portable mini-centrifuge for measurement of hematocrit and for centrifuging whole blood to obtain serum or plasma in micro-amounts

Total Protein (S/P)
The total protein of the serum is markedly decreased in kwashiorkor and in other forms of protein malnutrition. The bedside measurement of serum protein may be most useful in a rural environment of developing countries where protein malnutrition is an underlying factor in a variety of other disorders. Bedside definition of serum protein level can be made using a portable battery-powered microcentrifuge to separate serum in a capillary tube (see Fig. 3). A small drop of separated serum is then placed on the plate of a refractometer which is calibrated to give a direct reading of total serum protein concentration.

Urea (WB, P, or S)
Blood urea may be markedly elevated in either acute renal failure or chronic renal insufficiency. The measurement of blood urea is one of the oldest and most widely used clinical laboratory procedures for the study of blood. Studies of blood urea may be done at the

bedside with ready-to-react reagent systems such as Azostix® or with the instrument Seralyzer® which utilizes dry chemistry reagents. The Seralyzer is a small semi-portable reflectance measuring instrument which may be used at the bedside. A photograph of the instrument is shown in Fig. 7.

Fig. 4 Hemoximeter for measuring oxygen saturation

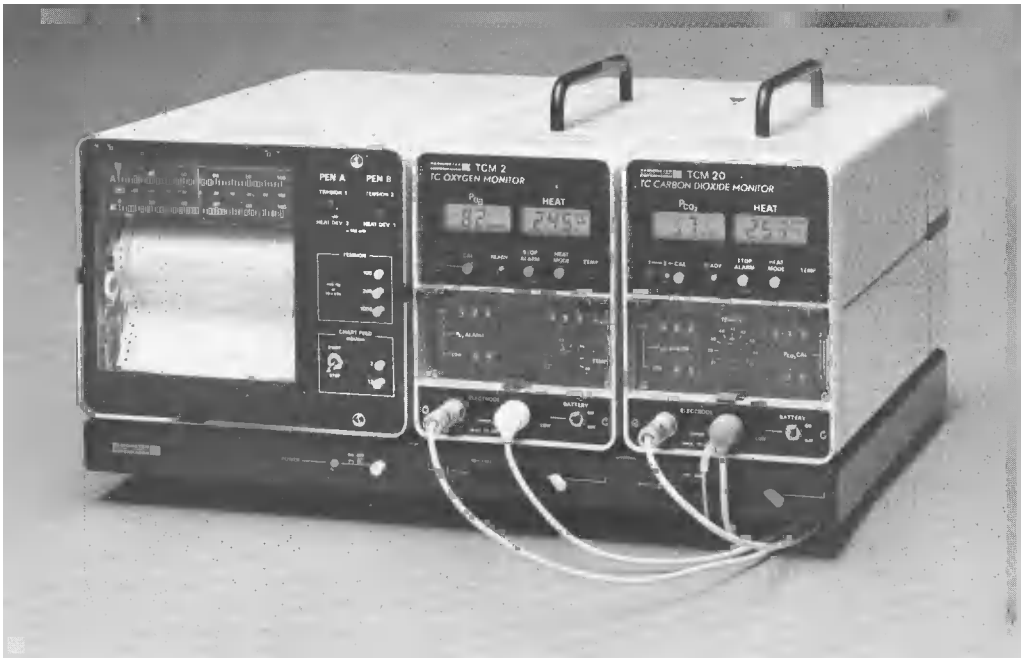

Fig. 5 Transcutaneous blood gas system for continuous automatic monitoring of both oxygen tension and carbon dioxide tension

Carboxyhemoglobin Fraction (WB)
In cases of carbon monoxide intoxication, measurement of the fraction of hemoglobin which is combined with carbon monoxide is useful for diagnosis and treatment. Bedside measurements are possible in an emergency room situation with an automated instrument when specially designed capillaries coated with dithionate are used to collect the blood. An example of such an instrument is the Hemoximeter which receives the deoxygenated specimen from the dithionate capillary and gives a direct reading of the HbCO fraction. This instrument is shown in Fig. 4.

Fig. 6 Biostator, a microprocessor-regulated glucose/insulin infusion system

Bilirubin (S/P)
Frequent rapid monitoring of blood for bilirubin may be required in newborn infants with abnormally increased bilirubin levels. Serum bilirubin levels are much higher in newborns than in older children or adults. Average maximum serum bilirubin levels of 6 mg/dL are reached in full term infants on the second to fourth day of life. In premature infants, average maximum levels of serum bilirubin of 10-12 mg/dL are reached on the fifth to seventh day. Excessive elevation of serum bilirubin or maximum levels for several days occurs in certain disorders such as hemolytic disease of the newborn (erythroblastosis fetalis) and may result in kernicterus. Kernicterus is a condition in which free bilirubin (unconjugated bilirubin) passes the blood-brain barrier and deposits in the fatty tissue of the brain causing irreversible damage to the central nervous system. Bedside monitoring of serum bilirubin in newborns at risk of kernicterus can be most important as an indication of when the critical level of bilirubin which requires exchange transfusion is being approached. Measurements of serum bilirubin are readily made with dry reagent systems such as Seralyzer or wet chemistry systems such as used with Bilirubinometer®

Salicylate (S/P)
Aspirin and other salicylate products have a worldwide usage. Problems of acute toxicity of aspirin in small children have a relatively high frequency. Many cases are caused by small children eating aspirin like candy while other cases are caused by parents who administer adult doses of aspirin to small children. An easy-to-do automated reagent system can be used

to identify salicylate intoxication. A specimen of urine is tested with Phenistix® which is a ferric ion test. A negative reaction in urine (i.e., no purple color) eliminates the possibility of salicylate intoxication. The appearance of a purple color after the strip is dipped in urine indicates the presence of salicylate and the need to test blood serum for further information. A small drop of serum or plasma is placed on a Phenistix reagent strip. If no purple color develops, there is no salicylate intoxication and the urine positive reaction is due to therapeutic doses of salicylate. A purple color appearing on the strip indicates that salicylate intoxication is present.

Fig. 7 Seralyzer, a reflectance colorimeter used with dry chemistry reagents to measure urea and other serum analytes

Erythrocyte and Leucocyte Counts (WB)

Sophisticated blood counting instruments are bulky and expensive. They do not lend themselves to operation proximal to the patient. However, somewhat simpler versions of red and white counting instruments are available and the cost and portability of these instruments provides the possibility that they may be part of the equipment in emergency rooms or in a laboratory adjacent to an intense treatment suite. One such instrument is provided by J. T. Baker Diagnostics. The Compur system provides a means of estimating the erythrocyte count indirectly by measuring the turbidity of a suspension of erythrocytes from a measured volume of blood added to a ready-to-use cuvette containing diluent reagent for suspension.

Bleeding Time (WB)

Bleeding time is a parameter which gives an indication of overall platelet function. Specifically designed instruments are available to produce a standard incision of the skin. An example of such a device is Simplate®, which is an instrument containing two attached blades which are released from the plastic hook which holds them by pressing a lever after placing the device on the forearm.

Anticoagulant Monitoring (WB)

Frequent monitoring of anticoagulant therapy is important in order to ascertain that the desired level of coagulation inhibition is maintained. An excessive degree of anticoagulation may lead to serious bleeding problems whereas inadequate levels may lead to intravascular thrombosis. One such reagent for control of oral anticoagulant therapy is Thrombotest®. It exhibits a high sensitivity to Factors II, VII and X and is insensitive to changes in the concentration of Factor V and fibrinogen. A specifically designed water bath is available for performing Thrombotest measurements at the bedside. Automated systems are available for use with partial thromboplastin time reagent systems which are adaptable to bedside use. This

test is used for identification of hemophilia A and von Willebrand's disease which are the most frequent congenital coagulation defects. The measurement of activated partial thromboplastin time (APTT) can be used for the control of heparin therapy and responds to decreases in Factor VIII, IX, XI and XII. Automated coagulation apparatus can be used which involves an optical endpoint determination. Cephotest (Nyegaard) is an example of a reagent system for this measurement.

Activated Recalcification Time (WB)
Activated recalcification time is a useful monitor of the in vivo anticoagulation status of patients being treated with certain anticoagulants such as heparin. Blood is drawn into a pretreated tube which is then inserted into a heated rotary mechanism which automatically signals the time of test completion. An example of the instrument used to carry out this measurement is the Hemachron®.

Endogenous Platelet Aggregation (WB)
The platelet aggregation of blood can be evaluated endogenously by means of an instrument which circulates blood through special filters. Aggregation of platelets causes measurable pressure changes within the system. These pressure changes are directly related to platelet aggregation. An example of such an instrument is the Filtragometer®.

Urine Studies
Urine provides a wide variety of information which is useful in very many situations. The evolution of automated chemical reaction systems for the major constituents of urine makes it practical to study urine at the bedside without the use of automated instruments. Table 1 lists the chemical tests which may provide bedside information and also identifies the key information which can be of importance at the bedside. There is other information which may be important at the bedside but the objective of the table is not to provide a comprehensive tabulation of all of the possibilities. Some of this information is important in the primary diagnosis or monitoring of treatment. Other information may be useful in identifying secondary complications. Additionally other information may be pertinent in helping to rule out complications. For instance a urine pH of 6 or 7 minimizes the likelihood of acidosis. A urine specific gravity of 1.030 provides information that dehydration may be present whereas a urine pH of 1.015 makes dehydration most unlikely. Automated ready-to-react chemical systems are available for each of the 10 constituents listed in Table 1. Each reagent system when moistened with urine generates a color which indicates the presence or absence of the constitutent and if present the approximate amount. Visual measurements involve comparison with standardized color charts at specific times following the dipping of the reagent in the urine specimen. An automated instrument is available for reading the reacted colors of the first 8 constituents listed in Table 1. A multiple reagent strip such as N-Multistix® is dipped in the urine specimen and then placed on the tray of the instrument which following activation makes a reflectance reading of the color of each reacted area. Results are then displayed on a lighted panel or also can be processed through a printer or entered directly into a computer. An example of an automated instrument for reflectance reading of reacted dip-and-read urine strips is Clini-Tek®. Fig. 8 is a photograph of Clini-Tek.

TABLE 1. Information from Urine

Constituent	Information
Glucose	Unregulated diabetes
Ketone	Possible Ketoacidosis
Bilirubin	Viral or chemical liver injury
Urobilinogen	Hepatic dysfunction
Blood	Intravascular hemolysis
pH	Suggests possible acidosis or eliminates possibility
Nitrite	Urinary tract infection
Protein	Renal glomerular lesion
Specific Gravity	Suggests possible dehydration or eliminates possibility
Leucocytes	Inflammation of urinary tract

Frozen Sections (T)
Bedside or patient proximity measurements have an important utility with relation to examination of biopsy tissue for evidence of malignancy. A typical situation is the surgical examination of a deep organ or body area in the surgical amphitheatre. The surgeon makes a biopsy of the organ or suspected tissue, and gives the tissue to the pathologist or technologist who promptly freezes the tissue in a block of dry ice and then makes frozen sections for microscopic examination. Meanwhile the surgeon awaits the verdict of the pathologist examining the sections as to whether or not malignancy is evident as a basis for the course of further surgical intervention. The preparation of the frozen sections is carried out with an instrument called a microtome-cryostat. This is a mobile electropowered instrument which has

the capability of freezing a piece of tissue quite rapidly. The frozen tissue is then sectioned by a microtome contained within the refrigerated area to provide ultra-thin sections of tissue. These sections are then mounted on slides and microscopically examined for specific cellular structural characteristics by a pathologist. This bedside or patient-proximal procedure incorporates the function of the clinical laboratory scientist as a key member of the medical-surgical team.

Fig. 8 Automated instrument for reflectance reading of reacted urine dip-and-read reagent strips.

Ethyl Alcohol (Breath)

The measurement of the amount of ethyl alcohol in the expired air is utilized in medico-legal situations as a measure of intoxication. The measurement also has applicability in the emergency room or the admitting facility of a hospital. An example of an automated instrument for measurement of alcohol in expired air is the Breathalyzer®. This instrument measures the alcohol content of the "deep lung breath" or the last portion of expired air. This air reflects the equilibrium in the lungs between the alcohol in the blood and that in the alveolar spaces of the lungs. The subject blows forcefully into the inlet tube and a unique piston arrangement allows the first portion of the expired air to escape but directs the last portion of each breath to bubble through a reagent system. The reagent generates a color change which is proportional to the alcohol vapor in the alveolar air. An integrated colorimeter measures the color and shows the result in terms of blood alcohol concentration on a display panel.

Rapid Cold Agglutinin Test (WB)

This test detects in a minute or two the cold agglutinins which increase in primary atypical pneumonia or in certain hemolytic anemias. The test can be performed on fingertip blood; 0.2 mL blood is allowed to run into 0.2 mL of 3.8% trisodium citrate in a small (60 x 7 mm) test tube. The tube is corked, rubbed over an icecube tray of a refrigerator and placed on its side in the tray for about 15 seconds. It is removed (holding by the cork to avoid warming) and is slowly rotated so that the mixture runs gently over the chilled tube surface. Coarse flocculant agglutination is recorded as positive. No agglutination or the presence of fine granularity is recorded as negative. The tube is then warmed in the hand for a few seconds and re-examined to confirm that all agglutination has disappeared. A positive test corresponds to a test tube titer of 1:64 or higher which is abnormal.

ADVANTAGES AND LIMITATIONS OF BEDSIDE TESTING

Some of the advantages of bedside testing are obvious and some are more subjective. One of the more obvious is the faster time for obtaining results. This can be of extreme usefulness in several ways. First, it produces prompt critical information. It can also provide the result while the physician is still with the patient so that the test result can be correlated with the physician's examination and thus promptly become part of the patient's total picture. Rapid results can also lead to faster sequential testing--testing which is performed or not performed depending on the original test results. Another obvious advantage of bedside testing is the earlier institution of treatment or therapy. Prompt test results also lead to more effective monitoring--quicker decisions can be made on changing treatment such as increasing or decreasing dosage, or administering a drug at shorter or longer intervals or

changing therapy altogether. Bedside testing can produce closer interrelationship between patient and laboratorian--especially in instances when laboratory personnel become involved with performing bedside tests as a routine--it makes the laboratorian more a part of the team. Sometimes a complaint is heard from the laboratory that the clinicians do not give sufficient attention to laboratory results. It is likely that in some cases such complaints are invalid, but in some instances they are valid. Bedside testing, particularly when the physician is present is likely to create an enhanced awareness and utilization of laboratory information. Another advantage of bedside testing is that the instrumentation and technology used at the bedside may have other important applications or may lead to other applications. For instance, technology used in the Biostator which automatically measures blood sugar through continual sampling through a cannula and injects glucose or insulin as the hospitalized patient requires based on the blood glucose result, has proceeded through miniaturization steps and may soon be applied to new devices which perform the same function but are small enough for diabetics to carry on their person. It is difficult to measure cost-effectiveness over such a wide variety of instrumentations and methods used at the bedside. Some methods are obviously cost-effective if they decrease patient hospitalization days. Others may or may not be cost-effective depending on the comparisons made and the viewpoint of the evaluator.

As with any kind of laboratory testing, bedside testing also has limitations. There may be errors due to poorly trained personnel. Some of the bedside methods appear so easy and simple that there might be a tendency for poorly trained persons to use them without regard for specific necessary knowledge required for proper usage. In this same type of situation there is likely to be a lack of concern about effective quality control programs, and the use of controls could be inadequate for best results. It is also possible that with infrequent use, or with misuse, instrumentation may malfunction. Such malfunctions may occur in subtle ways so that untrained personnel are not aware of the difficulties. Also malfunction may arise from improper maintenance or lack of it altogether. On the other hand, bedside instrumentation such as intensive care monitoring units are subjected to the closest scrutiny and the best possible control and maintenance. Extra costs are another possible limitation to bedside methods. Required capital investment obviously will contribute to higher costs if the instrumentation is at all expensive. Actual cost per test may be significantly higher for bedside tests but in many other examples may be significantly lower when compared to regular routine laboratory tests and overhead expense. The limitations suggested can be avoided if there is adequate training, supervision and effective use of control and maintenance.

FORECASTING THE FUTURE

The future of bedside testing provides an intriguing topic which can encompass a wide variety of attitudes and opinions. The total field of clinical laboratory science is a rapidly growing one and has experienced impressive changes within the past two decades. These changes have evolved primarily because of the realization of the important contribution of clinical laboratory information to health delivery. There is no current basis for a prediction that clinical laboratory science will not continue to flourish and make an even greater contribution within the next two decades. Correspondingly it is realistic to envision that bedside testing will play an increasingly important part in the overall growth of clinical laboratory science and automation. Table 2 identifies some of the influences which will have an impact on the future of bedside study. These and possibly other factors will influence

TABLE 2. Influences on the future

1. Emerging technology
2. New diagnostic analytes
3. New methods of treatment
4. New understanding of clinical utility
5. Quality of information
6. Convenience
7. Cost
8. Personnel
9. Safety

the final result. There are several areas of bedside clinical laboratory study which are likely to receive special attention and special benefits. Computers and electronic data banks have the potentiality of making dramatic contributions. Miniaturization of instruments and data handling devices is a trend that will gain momentum. Microbiology, hematology and immunology will profit by increasing research and technology and should become much more important in bedside study. Finally the potentialities of the professional laboratory scientist will be expanded by the bedside component of the whole field. Health delivery has improved the quality of life and will continue to do so in the future even though the manner in which it functions is an ever-changing one.