Self Testing, An Emerging Component of Clinical Chemistry

Alfred H. Free and Helen M. Free

The past, present, and future of self testing is reviewed and discussed.

Introduction

The appearance and growth of self testing brings to clinical chemistry an interesting and significant development. Self testing is an activity in which a clinical laboratory measurement is made by a lay person who has neither the resources of a laboratory nor the technical, medical, or scientific training ordinarily involved in the testing and the use of the information provided. Ordinarily it is considered to include not only measurements made on specimens from one’s self but also measurements made by a family member or associate. The terms “self testing” and “home testing” are considered to be synonymous in this discussion; we prefer the former term, because much of such testing occurs outside of the home. Currently, most self testing is on the basis of a program recommended by a physician. Correspondingly, the results of self tests are recorded and the results reviewed with a physician, who interprets them and proposes further action. However, the concept of self testing does not necessarily involve a role by a physician or laboratory scientist. The person carrying out the activity may plan and carry out further actions on the basis of the results.

An excellent example of a self-testing activity that is frequently carried out without consultation with a professional is the monitoring of one’s body weight. The distribution and ubiquity of bathroom scales and scales in various health facilities attest to the interest and concern that body weight holds for many persons as a self-testing procedure. The measurement of body temperature is another self-testing procedure commonly used by lay persons. In many instances the results of measuring one’s temperature is the basis for consulting or not consulting a physician. Indeed, the measurement of body weight and the measurement of body temperature by self testers make very significant contributions to health delivery.

Historical Background

Self testing with use of clinical laboratory tests is not a new concept. Elliott P. Joslin, in the early part of the 20th century, before the discovery of insulin, advocated that patients with diabetes should avoid ingesting most carbohydrates and should monitor their compliance with such dietary practice by frequent urine testing to keep it sugar free (1). The only test available for doing so was Benedict’s qualitative test. With the advent of insulin as a treatment for diabetes in 1922, self testing of urine became more popular—and the Joslin Clinic, the prime advocate of self testing for sugar in urine, became the most famous diabetes clinic in the world.

The creation of Clinitest® Reagent Tablets by Walter A. Compton, then a recent graduate of the Harvard Medical School, and Maurice Treneer, a pharmaceutical chemist and an expert tablet maker, made testing of urine for sugar much more convenient (2). Clinistix® is a dry tablet that contains sodium hydroxide, citric acid, sodium carbonate, and cupric sulfate. When the tablet is added to a small quantity of urine in a test tube, the tablet reacts rapidly, generating sufficient heat to cause the mixture to boil. If glucose is present in the urine, it is oxidized and the blue cupric sulfate is reduced, causing a change in color from blue to green to yellow to orange. This procedure provided such convenience that the test was used by many diabetic patients themselves as well as by physicians’ office laboratories and hospital laboratories. The test was the first commercial clinical-laboratory test system and was the first clinical-laboratory system to be used to any extent in self testing. It also was the first dry-chemistry clinical-reagent system (3).

A second system to become used in self testing was Acetest® Reagent Tablets. This reagent system was evolved by a small group in the Miles—Ames Research Laboratory of which both of us were members (4). This product, primarily designed as a convenience product, could be used at home by diabetic patients as a means of recognizing impending ketoacidosis. It was a very important adjunct to the treatment of diabetes, because ketoacidosis was at that time still a significant killer of persons with diabetes. When a drop of urine containing ketone bodies was placed on the surface of the white tablet—which contained sodium nitroprusside, glycine, and buffered sodium phosphate—a bright purple color promptly developed. With urine not containing ketone bodies no purple color developed. This test system not only was used widely by patients with diabetes, but also in hospital laboratories and physicians’ office laboratories, where it gradually replaced Rothera’s test, which was a cumbersome, non-standardized test. The acceptance of Acetest as a means of self testing followed the teachings of Joslin (1) and his pupils that diabetics should be responsible for a major part of their own care. Acetest is still widely used throughout the world 35 years later. An even more convenient test system was introduced with the concept from the Ames Research group of dip-and-read testing. Clinistix® Reagent Strips (5), a test for glucose in urine based on specific enzyme reactions of glucose oxidase followed by catalysis of peroxidase oxidation of a chromogen to produce a color, were made available in 1966. At about the same time, and Eli Lilly and Company produced TesTape®, based on a comparable series of reactions. These tests impressively broadened the use of self testing of urine by diabetics. And

Ames Division, Miles Laboratories, Elkhart, IN 46515.
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not only did this convenience approach to the examination of urine broaden the self testing by patients with diabetes, it was the basis for subsequent analytical chemical systems for all types of urine tests (6).

Dextrostix® Reagent Strips were introduced in 1964 as a rapid disposable test for blood sugar. This reagent strip was based on the same concepts of dry chemistry and convenience as Clinistix, Acetest, and Clinistixtests. The ready-to-react reagent system contains glucose oxidase, peroxidase, and a chromogen system that develops color when the enzymes catalyze the oxidation of glucose in the blood. A semipermeable membrane covers the reagent area, so that when a drop of whole blood is placed on the reagent, soluble glucose passes through the semipermeable membrane and reacts with the reagent to give a blue color. After the blood has been on the strip for exactly a minute, it is washed off and the color is matched to a series of color blocks. This test became extensively used by physicians in office practice and in emergency-care centers. It was not designed to be used in self testing. In the U.S.A. it was not possible for a diabetic to buy the test; the physician had to buy the test and pass it along to the patient. In 1969 this test system was further refined by addition of a reflectance reading instrument (7). This provided a confidence factor for many physician and laboratory users of the test. The first instrument was small and heavy. It was made of metal and about the size of a transistor radio of the time. Its weight was due in great part to the rechargeable battery. The blood glucose concentration was read from a needle/dial face calibrated in mg/100 mL. A later model, the Dextrometer® Reflectance Colorimeter, was useable only with electrical outlets, but it was lightweight and presented the result in digital readout form. The present instrument, the Glucometer® Reflectance Photometer, is entirely portable, battery-operated, and “user friendly,” because the one-minute timing is automatically counted down on the digital readout panel and a sound signal indicates the beginning and the end of the timing period. The small, hand-held instrument is easy to learn to use.

The simplicity of the technical maneuvers and the convenience of using Dextrostix generated interest in certain areas of Europe regarding the self testing of blood sugar by patients with diabetes (8, 9). The group of particular interest was diabetic women who were pregnant or who had an intense interest in becoming pregnant. With these patients the concept of “normalizing” the blood sugar became the objective. Normalization of blood sugar means trying to maintain blood sugar at concentrations similar to those of non-diabetics, without the wide swings to very high and very low blood sugar values that are common in diabetics. This is accomplished by frequent monitoring of blood glucose. Figure 1 shows typical 24-h curves of diabetics receiving traditional therapy with insulin and diabetics receiving multiple small insulin doses, with blood-glucose monitoring at frequent intervals. Clearly, the normalization of blood glucose concentrations with this new regime provides a more stable carbohydrate metabolism than does the typical two-injections-per-day insulin system. It is interesting that Dextrostix was marketed to physicians and laboratories for 15 years before it was even investigated as a procedure for self testing in the U.S.A.

The Factor of Medical Relevance

The initial basis for self testing was to provide critical, medically relevant information that was not available from any other source. At the time of the discovery of insulin there were no laboratories where a diabetic patient might get a urine specimen tested for glucose. The only alternative was for diabetics to test their own urine. Joslin et al. (1) and other early diabetologists recognized that it was not practical to prescribe a dosage of insulin based on body weight or on the basis of the urine or blood studies made at the time a patient was hospitalized.

Self testing of urine for glucose during the period from 1922 to 1941 was cumbersome and difficult. As a result, only a very small proportion of patients tested enough to satisfactorily regulate their diabetes. During the next 20 years the advent of tests specifically adapted for self testing resulted in a great increase in self testing of urine by diabetic patients.

The medical relevance of self testing of blood sugar is vividly described in the publication "Diabetes Management in the '80s," derived from a symposium held at The Rockefeller University in November 1980 (10). Prior to blood glucose control by self testing, miscarriages and stillborn babies were frequent in diabetic mothers, with rates of perinatal mortality as high as 50% in cases where the control of diabetes was poor. Furthermore, various problems occurred in newborns: congenital malformations in 5 to 18% of cases, cerebral dysfunction in 20 to 36%, macrosomia in 16 to 40%, hypoglycemia in 16 to 76%, hypocalcemia in 8 to 22%, erythema in 10 to 45%, hyperbilirubinemia in 9 to 35%, and respiratory distress in 2 to 9%. When self testing control of blood sugar was instituted prior to conception and vigorously followed throughout pregnancy, there was a negligible incidence of all of the above-mentioned morbidity (11). It has also become recognized that even modestly increased blood sugar concentrations result in the glycosylation of hemoglobin and other body proteins (12). Normalization of blood sugar by frequent self testing of blood sugar and careful spacing of insulin dosage minimizes this glycosylation of body protein. Increasing evidence suggests that normalization of blood sugar minimizes the likelihood of encountering many of the secondary complications of diabetes, which include blindness, renal failure, foot problems, impotence of males, neuropathy, skin lesions, and cardiovascular disease (13).

Urinary-tract infection is frequent in females. Not only is such infection disagreeable, but the possible permanent damage to the kidney makes this disease important to recognize and treat promptly (14). A test for nitrite (15) or leukocytes (16) in urine provides a means of recognizing the infection early, at a time when the infection is most susceptible to treatment.

Both clinical laboratory science and medical practice are rapidly changing. There is not always complete agreement among medical practitioners and laboratory practitioners as

![Fig. 1. Normalized blood glucose response of a diabetic controlled by multiple insulin injections and several small meals, based on multiple self tests each day, as compared with typical blood glucose response of diabetic controlled with two insulin injections per day](image-url)
o what is medically relevant and what is not. As self testing involves one finds disagreement with regard to whether specific self-testing practices are or are not medically relevant. Continuing and growing use of a self-testing procedure provides support for the medical relevance of the procedure. Actually, this is no different from the situation as it relates to clinical-chemical procedures carried out in the laboratory.

The Factor of Convenience

Benedict's test (17) for the recognition of sugar in the urine was devised in the very first part of the 20th century. It was a product of the work of Stanley Benedict, who was in medical school at the time. Benedict's qualitative test for sugar in the urine was the test recommended by Elliott P. Joslin, who incorporated self testing for urinary sugar into his patient-care program for diabetics even before insulin was available for use. Benedict's test was easy to do in a laboratory. It is much more of a problem for a diabetic without any laboratory experience and without a laboratory! And this lack of convenience is compounded by several orders of magnitude if one envisions performing the test at work or while (e.g.) on a trip away from home. This problem was emphasized to us in recent conversations with a friend from our community, Mary Ellen Mirza. She was diagnosed as a diabetic in 1932 as a young child. When she went away to college, she took with her a bottle of Benedict's solution, an alcohol lamp, and a large long-handled porcelain-coated metal mixing spoon, so she could test her urine for sugar. In spite of the inconvenience of those early days, Mary Ellen maintained good control of her diabetes during her school days and during a successful pregnancy (long before days of multiple injections of insulin with multiple blood-glucose measurements for normalization of blood glucose during pregnancy), with a successful home and social life, and in 1982 she was awarded one of the Joslin Clinic's 50-year medals for having successfully coped with her disease for half-a-century!

The first recognition of a convenience factor in self testing was the introduction of Clinitest in 1941 (2). This test was devised for the convenience of laboratory personnel as well as patients. However, with its immediate acceptance for use in the laboratory and in the physician's office, it became apparent that its convenience was an attribute that would appeal to diabetics for self-testing—and the convenience of the test made it much more likely that the recommended testing regimen would be followed. Ever since, any consideration of clinical chemical self testing has tended to have convenience as a cardinal feature. In fact, we in the laboratory like "convenient" as an adjective to describe our procedures and instrumentation—except that with laboratory instrumentation today, instead of speaking of "convenient" aspects of automated instrumentation, we speak of instruments that are "user friendly."

The Factor of Cost Containment

Costs have become a dominant factor and a matter of widespread concern in health-care delivery. Hospitalization stays are being shortened. Self care and self responsibility for many aspects of health are being emphasized, and self testing is receiving greater emphasis. A recent monograph on self testing (18) gives continued attention to the cost-containment factor. Very few clinical chemists in the U.S.A. have not been exposed to the concepts and practices of cost containment, and few have not heard of DRGs (defining the length of hospital stay and total reimbursement based on the diagnosis categorized into Diagnostic Related Groups). Both DRGs and cost containment have become matters of concern because they may substantially decrease the amount of testing performed in hospital laboratories. A major part of the cost of laboratory tests relates to the service and overhead charges; thus, if some tests can be moved out of the laboratory, costs to the patient are reduced. Earlier discharge from the hospital is likely to increase the amount of self testing.

Cost containments, including DRGs, are likely to slow the rate of growth of hospital laboratories. We doubt that DRGs or other cost-containment measures will actually significantly decrease the current size of laboratories. As new tests become part of the program, other tests that can be done by self testing will be done less frequently in the laboratory and will, at least in part, be established in the self-testing area. Currently, total health-care costs in the U.S.A. are estimated to be about $325,000,000,000 (19). Only a relatively small portion of this enormous total represents actual laboratory costs. In order to prevent the continued growth of health-care costs, changes throughout the entire system will occur. The laboratory group is the most logical one to assist in devising and expediting self-testing training programs.

Other Factors Influencing Self Testing

Several additional factors may prompt and account for self testing. These factors are substantial but not of the same magnitude as the preceding ones.

Secrecy/fear. In some situations the reason for self testing is that the person doing the testing does not want the result to be known—pregnancy or venereal disease are examples. Occasionally the factor of fear is involved with self testing. It may prevent persons from going to the laboratory for a cancer test because the laboratory personnel would know the results. Others may fear that their associates or family may consider them hypochondriacs if they go to a laboratory for tests.

Isolation. Persons in isolated situations may have no access to a laboratory and accordingly may carry out a self-testing program. Explorers in primitive areas may have a significant need for certain information that can only be obtained by self testing. A recent article by a backpacker who had diabetes describes a six-day solitary hike. This person did four blood-sugar measurements each day in the wilderness to properly interrelate energy expenditure, food intake, and insulin dosage (20).

Research. A significant interest and activity in self testing is related to research. The great impact of the current practice of self-testing of blood sugar on the course of pregnancy in the diabetic would not have been discovered without careful research. This great improvement in the course of pregnancy, both for the mother and the prospective infant, is an excellent example of how unexpected beneficial results may be obtained through research. Much research is being carried on, not only to explore the utility of new self-testing programs but also to document current programs and improve their effectiveness and eliminate identified problems.

Currently Available Self Tests

Several currently available tests or reagent systems can be used by lay individuals or members of their family for self testing. These are briefly described in the following paragraphs.

Urinary glucose. Several tests for glucose in urine are available from different commercial sources. These tests are widely used throughout the world in self testing, to monitor the treatment of diabetes (21-24).

Urinary ketone bodies. Reagent systems for self testing of urine for ketone bodies are used by patients with diabetes as
a means of recognizing impending ketoacidosis (25). These tests are also used as a means of monitoring weight-reduction programs based on low carbohydrate intake (26). Combination ketone and glucose tests are also used in self-testing by patients with diabetes (27).

Urinary nitrite. About 90% of urinary-tract infections are caused by microorganisms that can reduce part of the nitrate in urine to nitrite. A test for nitrite in urine is therefore a rapid and effective means of self-identification of urinary-tract infection. The urinary nitrite test is also a means of monitoring the effectiveness of treatment of such infections when they are caused by nitrate-reducing bacteria. Kunin (15) states that he believes that "the nitrite method is the chemical test with the greatest potential in screening and for following patients," and he recommends that his patients test their own urine and contact him if a positive result is obtained.

Urinary protein. Proteinuria is an early indicator of impaired renal function. Diabetics who are quite likely to encounter renal impairment as a secondary complication can utilize self-testing for urinary protein to advantage (28).

Occult blood in urine. Occult blood occurs in urine in a variety of conditions. The possible development of glomerulonephritis in acute infections is recognized by self-tests for occult blood in urine (29).

Choriogonadotropin in urine. Recognition of increased amounts of choriogonadotropin in urine is the basis for most self-tests for pregnancy (30).

Relative density (specific gravity) of urine. Persons who develop a kidney stone are likely to develop recurring kidney stones—usually of the same type. For this special group of people, a self-testing dual-reactant strip, Lithia-test*, is available for monitoring pH and relative density (specific gravity) (31). The recommended means of avoiding recurrence of kidney stones is to ingest large quantities of fluid and also to maintain a urinary pH such that specific stone-forming constituents will remain in solution, and measurement of urinary specific gravity and pH effectively monitors this program. The specific gravity of urine is also an effective index to early renal tubular dysfunction (32).

Urinary pH. Urine pH is an effective exclusion test for ruling out the possibility of systemic alkalosis or systemic acidosis (33). The role of urine pH in urolithiasis is described above.

Urinary phenylpyruvic acid (PKU). Mothers can easily test for PKU in their own infants. Some years ago Dr. Paul Martin, Commissioner of Health in Elkhart County, IN, instituted a procedure whereby he gave each mother of a newborn baby a packet of three urine tests for PKU as she left the hospital. The mother was instructed to use the reagent strips on the baby's diaper when the baby was four to six weeks old and to look for a gray-green color development three times. When she reported the results to the County Health Department on a mail-back card, Dr. Martin then sent her a copy of her baby's birth record (34).

Urinary salt. Low-salt diets are commonly recommended for persons with hypertension. The self-testing of urine salt concentration gives an indication of dietary compliance. A convenient, easy-to-do test is available for estimating salt in urine (35).

Leukocytes in urine. Urine leukocytes have been identified in the past by microscopic examination of urine sediment. A dip-and-read test for urinary esterase, which is primarily derived from leukocytes, is a newer means of identifying urinary-tract infections (16).

Urinary uric acid. The concentration of uric acid in urine reflects the purine content of the diet. In gout and in cases of recurrent urolithiasis due to uric acid it is important to restrict purine intake. An easy-to-use dry-chemistry reagent system can be used to monitor urinary uric acid excretion, to avoid high purine intake and minimize the likelihood of an attack of gout or the development of a uric acid kidney stone (36).

Urinary urea. A low protein intake has been proposed for control of renal tubular disease. A self-monitoring test for urinary urea is an effective means of establishing that a low protein intake is being maintained (37).

Urinary calcium. Deficiency of calcium is very common in elderly women, and frequently results in serious bone injury such as broken hips and fractures of other long bones. A self-monitoring test for calcium in urine provides a means of self-testing, to identify whether treatment to minimize body calcium loss is effective (38).

Urinary bilirubin. Normally, no bilirubin is excreted in the urine. In cases of infectious hepatitis, bilirubin appears in the urine and disappears again with recovery from the disorder (39). A self-test for urine bilirubin provides a means for a hepatitis patient who has been discharged from the hospital to carry out daily tests for a period of two or three weeks so that a recurrence of the hepatitis is promptly recognized.

Occult blood in feces. Collection of stool specimens at home in special convenience packets for testing at a central laboratory has become widely established. This test is done for the detection of colorectal cancer, which causes bleeding into the gut (40). In the near future it is likely that the entire test will be done at home.

Fecal pH and glucose. Certain individuals have a genetic deficiency of lactase in their intestinal digestive system, and this causes severe symptoms after ingestion of milk or other foods containing lactose: intestinal cramps, diarrhea, bloating, and flatulence. After a glass of milk has been ingested, an acid reaction and a positive test for glucose in the stool, as indicated with dip-and-read tests, suggests lactose intolerance (41).

Blood glucose. Dry-chemistry systems for self-measurement of glucose in whole blood are now very extensively used in the U.S.A. Both instrumental and visual readings are made of the color reactions generated with the reagent systems (42-46).

Blood ketones. A self-testing procedure for measuring blood ketones involves the use of Acetest tablets with a drop of whole blood. The blood is placed on the tablet and allowed to remain for 10 min or until clotting occurs. The clot is lifted off, and if the surface of the tablet is purple, this indicates an above-normal blood ketone concentration (47).

Blood urea. A dry-chemistry test system is available for self-testing in which whole blood urea is measured in a drop of capillary (fingertip-puncture) blood. Such a test is useful in monitoring dialysis patients, to help decide when dialysis is required (48).

Hemoglobin of blood. One of the oldest self-test procedures for hemoglobin is the specific gravity method, which merely involves adding a drop of fingertip blood to a solution of copper sulfate. A drop of blood with a normal hemoglobin concentration sinks, whereas a drop with low hemoglobin will not. This test can be used to recognize anemia and to evaluate treatment for this condition (49).

Streptococcal antibodies in blood. The streptozyme test is a test for streptococcal antibodies, to identify the possible presence of streptococcal infection. The test is performed by mixing the reagent with diluted blood and looking for agglutination of the erythrocytes. Clumping or agglutination indicates recent or active streptococcal infection (50).

Hemoglobin S in blood. Hemoglobin S is an abnormal hemoglobin that causes erythrocytes to assume a "sickle"
shape, which in turn may inhibit proper circulation in the peripheral capillaries. Sickledex® is an agglutination test, used to detect hemoglobin S as an indication of sickle cell anemia or sickle cell trait (51).

**Throat swab for group A streptococci.** A throat swab test provides results in 10 min (52). Positive agglutination in the latex particle test prompts one to consult one's physician to institute prompt medical treatment.

**Vaginal swab for candidiasis.** A dry-culture test system for room temperature incubation of monilia is available. The test can provide confirming information of suspected infection, thus prompting medical consultation and treatment (53).

**Gonococci in urethral fluid.** A rapid test for gonorrhea involves the interaction of a drop of urethral discharge with an immunochemical reagent. If *Neisseria gonorrhoeae* organisms are present, a color change occurs in 10 min (54).

**Breath alcohol.** There are several relatively inexpensive breath-alcohol analyzers available that are readily operated by non-technical personnel (55). These meters measure alcohol in the breath but present the results in terms of blood alcohol concentrations. These devices are used in a self-test capacity, particularly after social drinking prior to driving on public highways.

**Breath carbon monoxide.** Carbon monoxide, a colorless and tasteless poisonous gas, is present in gasoline motor exhaust fumes, pipe, cigarette, and cigar smoke, and in smoke from almost any type of fire. The gas can cause serious permanent damage to nerve and muscle. Self testing is of very great significance in smokers, because it indicates that some have concentrations of carbon monoxide hemoglobin (carboxyhemoglobin) in their blood that approach acute toxic levels. Self testing can also reveal exposure to seriously high quantities of this gas from defective heaters and furnaces. Commercial systems for self testing involve an exhaled air-collection container, with the collected air sample being passed through an indicator tube to provide an indication of the amount of carbon monoxide present (56).

**Enhancement of the Quality of the Information.**

A requisite of self testing is that high-quality information be produced. No one factor can assure high-quality information; rather a combination of several activities are ordinarily required. Very little is to be gained if in self-testing activities the results are of poor quality. One should recognize that in certain instances good or bad results are a life or death matter. In a sophisticated clinical laboratory it is well recognized and well accepted that a good quality-assurance program must be established and followed. Correspondingly, a quality-assurance program needs to be followed by persons who are doing self testing. Such a program is not necessarily the same as that which may be carried out in a laboratory.

Table 1 is a check list that relates to a variety of self testing programs. Because of the great diversity of reasons for self testing and the great diversity of tests utilized, some of these may not apply to given situations and there may be others which should be added for certain specific self-testing programs. In the U.S.A. there are not many bona fide clinical chemical procedures provided by industry that do not have an ongoing scrutiny from the Federal Food and Drug Administration and are "high quality" within the framework of their labeling and manufacture. The directions for performing a test are quite critical. In some instances the test will appear to function even though there is some deviation from the defined procedure for use, but in specific cases the quality of the results may be impaired. We very strongly advocate that directions should be followed exactly as written. Some self tests should be maintained at refrigerator temperature and some have a sound basis for storage at room temperature. With "dry-chemistry" reagents, protection from the humidity of ordinary air is critical (i.e., promptly re-cap the container within 10 s after opening it). If results are not carefully recorded, in a permanent record place, much of the positive contribution of self testing is sacrificed. Trained analysts occasionally make errors, and so do people making self tests. For very many kinds of self testing, the first action after unusual results are obtained is to repeat the test. Education of the self tester is an important and continuing process. The consensus is that with any self-testing function—even if it is on a one-time test basis—the tester should understand why the test is being carried out.

For chronic disorders such as diabetes, renal disease, and many circulatory and respiratory disorders, the effectiveness and quality of self-testing efforts will be greatly enhanced with a continuing-education program regarding all aspects of the disease. Davidson has discussed this in relation to diabetes (45). There is a national organization known as the American Association of Diabetic Educators in the U.S.A., with approximately 2000 members, who function primarily in the continuing education of persons with diabetes. If an unusual result is confirmed by a re-test, a plan of action relative to response to the unusual result should be established. The regular schedule for checking of testing material with controls to give both positive and negative results should be established. With urine sugar tests this might involve testing a urine from a non-diabetic member of the family for a negative control and a teaspoon of the same urine with three drops of corn syrup added might be used for a positive control. For many tests, controls are part of the system or can be purchased separately. Very few special-proficiency programs are available for persons doing self testing, but generally the producer of a test system can provide information on applicable programs. Product inserts for test reagents have much information,
along with specific suggestions and proscriptions. Regular
and repeated reading of this valuable information is signifi-
cant for maintaining and enhancing the quality of results.

The Role of the Physician

Currently, much self testing is being done at the suggest-
ion and under the direction of physicians. The clinician has
also been the principal interpreter of self tests. This is likely
to continue but additional areas of self testing may evolve.
We have already mentioned the role of one physician in the
PKU self-testing project. Another simple "test," which can
prompt mothers to call a condition of their babies to the
attention of their pediatricians is the so-called "kiss test." It
has been publicized that parents should be aware of the
saltiness of their baby's skin when they are kissed, as a
possible indication of cystic fibrosis. This type of awareness
is of great help to physicians in determining the health
status of infants. Organizations and health agencies often
sponsor certain types of clinical chemical testing at health
fairs. This type of alternative site testing can be considered
the forerunner of actual self testing or testing members of
the family; these are always under the auspices of physi-
cians' groups such as the local medical society, whose role is
interpretation and referral.

In some parts of the world, government or schools have
carried on large-scale routine screening for common abnor-
malities shown by positive urine tests for protein or glucose
or occult blood or nitrite. Abnormalities are then referred to
physicians for follow-up.

Many physicians include a urinalysis with every work-up
of every patient on each visit. With the increasing trend
towards self testing, this may be changed so that the patient
appearing for a physical examination brings not only his
medical history form but his preliminary testing form filled
out to include the results of the tests his physician asked
him to do at home. Many physicians have recommended
that their patients become more involved and responsible
for their own health care. Self testing is one aspect of this,
and indeed is the subject of the book written by a physician
and his wife called "Do-It-Yourself Medical Testing," in
which more than 160 different tests are described that are
applicable to self testing (18). Busy physicians will welcome
the chance to spend more time treating sick patients—
which is what their training best qualifies them for. It would
not surprise us if there were "health" specialty physicians at
some time in the future, who would concentrate on main-
taining health and well-being instead of treating the sick.

The Changing Role of the Clinical Chemist

The field of clinical chemistry is changing. Some people
jokingly refer to the AACC as the "American Association of
Changing Chemistry." The AACC has had a history of
change. Originally, the group who formed the American
Association of Clinical Chemists consisted of a few analyti-
cal chemists who did analyses on body fluids. Throughout
the ensuing years, the role of the clinical chemist has
changed—really broadened—to include a variety of major
areas and somewhat different disciplines (Table 2). The
automated instrumentation we see in the clinical laboratory
today was not envisioned by our founding fathers (and
mother Mim Reiner!).

Immunochemistry and immunochemistry are two logical fields
for expansion, but only recently have clinical chemists
become involved with contributions to microbiology and
hematology. We have certainly been almost completely
responsible for the advent of therapeutic drug monitoring
and the contributions to patient care that it has made. And

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<th>Table 2. The Changing Role of the Clinical Chemist</th>
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<tr>
<td>Analytical Chemistry—1912 to present</td>
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<tr>
<td>Instrumentation—1946 to present</td>
</tr>
<tr>
<td>Quality Control and Data Handling—1950 to present</td>
</tr>
<tr>
<td>Microbiology—1970 to present</td>
</tr>
<tr>
<td>Immunochemistry—1970 to present</td>
</tr>
<tr>
<td>Therapeutic drug monitoring—1973 to present</td>
</tr>
<tr>
<td>Hematology</td>
</tr>
<tr>
<td>Immunology</td>
</tr>
<tr>
<td><strong>Self testing—challenges and opportunities</strong></td>
</tr>
<tr>
<td>Creator of methods</td>
</tr>
<tr>
<td>Creator of training programs</td>
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<td>Involvement of training</td>
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<td>Creator of quality assurance programs</td>
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<tr>
<td>Interface with end users</td>
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<td>Interface with clinicians</td>
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<td>Interpreter of test results</td>
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<td>Researcher of new applications</td>
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Educator

the whole field of quality control and data handling as well
as laboratory management and administration was created
in part by clinical chemists who recognized the changing
needs of the clinical laboratory.

Obviously, self testing will never replace the clinical
chemistry laboratory. But it is a change that clinical chem-
ists can use as an opportunity for contribution to health-care
delivery in an expanded way. The changing role of the
clinical chemist will include more emphasis on research
and development of self-testing methods and of more tradi-
tional methods, as well as new and improved applications
of existing tests and procedures. Clinical chemists will create
training programs; this is an opportunity for clinical chem-
ists to utilize their expertise in laboratory analysis to assist
group physicians and satellite laboratories in the education
and training of individuals in self testing—and indeed in the
education of physicians themselves in interpreting test
results. No one is more qualified than a clinical chemist to
establish proper quality control and proficiency testing by
self testers, for that will be a very important adjunct to the
use of such tests. As clinical chemists we have often com-
plained about "not being involved with the patient." Self
testing affords us the opportunity to become involved with
the "end user" of our product—our product being high-
quality test results. The clinical chemist is the member of
the health-care professional team most qualified to teach
the benefits of and the "how to's" of good laboratory practice.
As more and more testing becomes decentralized, the clini-
cal chemist can create a way to help the clinician and the
patient maximize the utility of self testing. With the use of
innovation and creativity the clinical chemist can change
his or her role to broaden the impact of the clinical chemist
on total health-care delivery.

834 CLINICAL CHEMISTRY, Vol. 30, No. 6, 1984
Does Self Testing Mean Job Displacement?

Self testing and its expansion in the years to come will probably have less negative impact on the clinical chemist than many anticipate. The extent of negative impact and the corresponding balance of positive impact will depend on the amount of innovation and creativity the clinical chemist can bring to his or her profession. We recall when automation first entered the clinical laboratory. Clinical chemists and medical technologists both feared that there would no longer be jobs for them in the clinical laboratory; "machines" were going to take over. To our knowledge, not very many jobs in the clinical laboratory were lost with the advent of automation, but jobs did change. And jobs will change with the increase in self testing. This changing role is due not only to self testing but to the entire changing gestalt—the whole picture of changing health-care practice.

Specifics of the changing have already been discussed. Many clinical chemists will be needed to fill the ongoing positions in hospital laboratories, reference laboratories, and specialized medical-center laboratories. Many will be needed in industry to research and develop new clinical chemistry systems, not only for self testing but for expanding ventures into new types of laboratory analysis. Who would have predicted the meteoric rise of therapeutic drug monitoring when the first procedures were introduced about a decade ago? Who would have predicted the permeation of radioimmunoassay and subsequent enzyme immunoassay into routine clinical chemistry for determination of a myriad of analytes when Yalow and Berson first published their insulin assay nearly 25 years ago? These innovations increased the need for clinical chemists. It is likely to be so for self testing. Rather than be displaced, the clinical chemist will be required to change.

Today there are no fields in which change is not occurring. Continuing education is the key word for economic survival in our changing profession. Continuing education from "g to g"—from "graduation to the grave"—is necessary to maintain our qualifications in emphasizing our changing role as creators, innovators, trainers, laboratory experts, and interfacers. With or without self testing, those clinical chemists who do not devote a very significant effort to continuing education for adaption to change will find difficulty—and those who do will thrive as the leaders of our profession.

Medico-Legal Considerations

During the past decade substantial attention has been directed to medico-legal matters in relation to very many aspects of health delivery. There is much debate as to whether this has had a positive or negative effect. Regardless of which type of effect is dominant, there is no question that medico-legal activity has contributed to the escalation of costs of health care.

Careful production of self-testing systems, coupled with effective packaging and clear-cut labeling, are responsibilities of the manufacturer. Responsibilities of the user include good training and thorough understanding of the nature and usage of the test, adoption and usage of a quality-assurance program, and involvement of a physician in the interpretation and use of the self-test results. Such a program involving the producer, the user, and the physician should minimize or eliminate medico-legal problems. Currently there are no major medico-legal problems relating to self testing of which we are aware, and with the activities described above there is no reason to predict any in the future.

If an unusual or unsuspected result appears with a self test, one of the best practices is to repeat the test and see if the same unusual result is obtained. Obviously, small differences are likely to be obtained due to the continuous changes that go on in body fluids. If a question arises relating to some test result, one should consult one's physician or, alternatively, contact the producer of the test. A clinical chemist or a pharmacist may be a good source of information relative to some questions relating to self testing. Dr. Edward Pinckney (18), a former editor of the Journal of the American Medical Association, has emphasized that no self test or any test in any hospital laboratory should be considered by itself as diagnostic. It is only one piece of information that aids a physician in arriving at a diagnosis.

Governmental Regulations

The regulatory climate that exists in the U.S.A. establishes that all medical devices—which includes in vitro diagnostic reagents and instruments used for clinical laboratory measurements—be subject to certain manufacturing procedures, certain quality-assurance procedures, certain labeling procedures, and certain marketing procedures. The manufacturing procedures are commonly referred to as "Good Manufacturing Practices." These practices relate to manufacturing facilities, record keeping of raw materials utilized in the manufacturing process, process controls and record keeping during the manufacturing process, and careful study of the finished product. The regulations provide for plant inspection (including access to records) by Food and Drug Administration officials. Quality-assurance information is required on raw material, intermediate products, and final products along with long-term stability studies. The labeling of in vitro diagnostic products must follow a protocol spelled out by the FDA, which includes an indication of composition, expiration date, specific instructions for use, limitations of the procedure, and conditions recommended for storage. In marketing of in vitro diagnostic compositions as controlled by the FDA, unwarranted claims for products are not allowed. Engelmann (57) has discussed the marketing, labeling, and regulatory considerations of diagnostic reagent systems used for self testing.

The regulations for products used for self testing are the same as those that apply to products used in clinical laboratories or in physicians' offices. As we have discussed here, most tests used in self testing are also used in clinical laboratories, hospitals, and physicians' offices.

The U.S. FDA also has specific regulations for the introduction of new in vitro diagnostic tests. These regulations are also the same for tests to be used in laboratories and/or to be used in self testing. Products to be used for self testing are required to follow the professional labeling protocol as defined by the FDA. However, self-testing products may also have additional labeling written specifically for the lay customer.

Impact on Clinical Laboratory Science

During the past seven decades, there has been an uninterrupted growth of new tests and an expanded use of both existing procedures and new procedures. As a result, clinical laboratory science has made an increasing contribution to health care. At the present time self testing is only a small part of the total of clinical laboratory practice. And in fact there are some who might maintain that self testing is not part of the total clinical laboratory science, because the manipulation of the measurements actually is not done in the laboratory nor are the results entered into the computer data system of the hospital. We believe quite strongly that home testing is part of clinical laboratory practice and that the clinical laboratory is the source and sustenance of self
testing. Correspondingly, the activities of self testing are actually making an increasing contribution to the laboratory. In the future this interdependence will become stronger and it would be most unfortunate for the end-user of each—the patient—if this interrelation does not flourish.

Modern health delivery is a “team” effort; it involves a number of team members, one of the team being the end-user (patient). To present a total picture of the team and its interrelationships. Figure 2 presents an ultra-simplified concept of the team and its interactions.

Self testing by the patient provides an added active involvement of the end-user as a team member. The object of the game is to continue the impressive improvement of health delivery to the end-users, regardless of whether they are “sick” or “well.”

Predictions for the Future of Self Testing

Table 3 suggests that there will be improvement in the quality of the systems used for self testing and in the quality of patient response resulting from the application of self-testing information. Research by both scientists and clinicians will be augmented. The scope of self testing will be broadened and will encompass healthy persons both in populous areas of developed countries and in rural areas of developing countries. The use of self testing as a means of study of large population groups, both for data collection for computer input and analysis and pinpointing of specific disorders, is becoming practical. But thus far it has not been utilized to any significant degree. It provides attractive potentialities for the future. If one attempts to predict the self tests that will evolve in the future, it is difficult to identify any area of clinical chemistry where self testing might or might not make a great contribution to health maintenance. It is also reasonable to envision that as clinical chemistry expands into new areas, self testing will likely follow and augment the contributions of science to good health and the quality of life.

Summary and Conclusions

Self testing as a phase of health delivery has been utilized for approximately 70 years, but within the last two decades there has been an increasing interest in and use of self testing. The practice of self testing has a sound basis, which involves medical relevancy, cost containment, and convenience. It is reasonable to anticipate that self testing will increase in the future as medical needs and available procedures are established.

The clinical chemist, the physician, and the industrial producer of test systems all have important roles in self testing. The clinical chemist, whether in a hospital laboratory or in an industrial setting, has the responsibility to create new self-testing procedures that represent expansion and improvement over those currently available. The clinical chemist also has a critical role in the evaluation of new self-testing procedures and in validating their capability of providing high-quality information. The provision of quality-assurance programs and proficiency programs for the user can most effectively be carried out by clinical chemists.

The clinical chemist can also play an important role as a consultant, teacher/educator, and trouble shooter in recognizing and helping solve problems that may appear in various areas of self testing. The classic role of the physician has been to diagnose disorders of the patients and provide therapy for effective care. The role of the physician in self testing is quite comparable to his usual role, since the ultimate diagnosis of disease will be carried out by the physician and he will continue to be the source for definition.

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**Table 3. Forecasts for the Future**

1. Expanded usage of self testing
2. Improvement of current tests
3. Better quality assurance and usage practices by the self tester
4. Better understanding of utility and limitations (by user and professional)
5. Research revealing new clinical usage of current tests
6. Research revealing importance of new parameters for self testing
7. Research and development of new and practical self tests
8. Testing of newborns in remote areas for inborn errors of metabolism
9. Screening by school children as part of health education
10. Self tests by patients prior to visiting a physician
11. Self tests by family members on growing children as part of permanent health record
12. Self testing by members of retirement communities
13. Regular self testing of large groups of persons in connection with computerized collection of health data
14. Self testing for persons in remote stations: space, deep sea, explorers, persons in isolated parts of the globe
15. Possible new self tests:
   - Cholesterol and lipids
   - Venereal diseases including syphilis, AIDS, and herpes
   - Rapid tests for identification of basis for severe diarrhea
   - Various serum and urine enzymes
   - Drug monitoring tests
   - Various metabolites and intermediates
   - Respiratory function tests
   - Urine tests for monitoring the quality of diet relating to vitamins, minerals, proteins, and purines
   - Quality of immunocompetence
   - Current level of nutrition

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![Diagram](Image)

**End User (Patient)**

**Laboratorian**

**Physician**

**Fig. 2. Interactions of self tester (end user), physician, and laboratorian—the team approach**
of therapy. A major portion of self testing will be carried out with the recommendation of a physician, and he will maintain a role in the interpretation of results. The physician needs to be familiar with self-testing practices and procedures and be prepared to provide interpretation of self-testing results. Industry supplies an increasing proportion of reagent systems and instruments for the clinical laboratory. The supplying of reagent systems and small instruments for self testing is almost completely a role of industry. The creation and funding of new products for self testing will be provided by industry to a large extent. A critical function of industry is to provide high-quality products and efficient customer service to the self-testing component of health delivery.

We have each played a role in self testing over a period of approximately 40 years. During this period self testing has become an important phase of clinical laboratory practice. We predict that it will continue to make important positive contributions to the progress of health delivery, not only for persons who are ill but also for persons who are in good health.

References

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52. For information on throat swab tests for Group A streptococcus infections, write to Marion Scientific, Division Marion Laboratories, Inc., Kansas City, MO 64114, or Hynson Wescott & Dunning (Becton Dickinson), Chase and Charles Streets, Baltimore, MD 21201.
54. Ref. 18, p 167.