Mass Screening for Diabetes in a Metropolitan Area Using Finger Blood Glucose after a Carbohydrate Load

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SUMMARY

New technical methods and instruments have made possible large scale screening for diabetes. A palatable, refreshing, carbonated drink, containing the equivalent of 75 gm. of glucose, was developed which makes possible uniform carbohydrate administration without nausea. Portable, automatic, analytical instruments, capable of rapid and accurate determination of glucose by a ferricyanide reduction method, were designed and built. Only .075 ml. of blood, readily obtainable from a finger prick, was required. The result was available in seven minutes, each machine being capable of forty analyses per hour. The equipment was incorporated into mobile units for testing in a community, or setting up in industrial plants.

Confirmatory carbohydrate tolerance tests were done whenever possible on all individuals having capillary blood glucose levels above 140 mg. per 100 ml., two hours after the carbohydrate drink.

In a completed Pilot Study, 8,790 individuals were screened, with 709 initially positive; 560 individuals returned for carbohydrate tolerance tests, and of these 407 had abnormal curves, for a total over-all incidence of 4.5 per cent.

An advantage of this method is that every individual screened has had, in effect, two carbohydrate tolerance tests before being referred to his physician. DIABETES *14*:295-99, May 1965.

The purpose of this paper is to present a method for mass detection of latent or early diabetes which is relatively inexpensive, rapid, and applicable to mass screening, and to report the actual application in a metropolitan area.

METHODS AND MATERIALS

The method consists of:

1. The oral administration of a carbohydrate solution.
2. Analysis of the glucose level of finger blood two hours after ingestion of the carbohydrate load.
3. The performance of a confirmatory, two-hour carbohydrate tolerance test on all subjects with screening blood glucose levels above 140 mg. per 100 ml.
4. Referral to the family physician.

A satisfactory glucose loading substance was not available. Candy bars[1] had been found to be unsatisfactory because people had to eat at least two bars (4.5 oz. total), which they occasionally failed to do. Some persons became nauseated. The standard 100-gm., lemon-flavored glucose solution, in general use, caused nausea in many of the people, and it has been shown that about one half of the glucose remained in the stomach after one hour rather than being absorbed.[2] Therefore, it became necessary to develop a new solution which satisfied the criteria of palatability and contained a satisfactory amount of glucose or substances which could be immediately hydrolyzed to glucose in the gastrointestinal tract.

This new carbohydrate loading solution, henceforth called "CL" is a partial hydrolysate of corn starch, commercially available as corn syrup. It was flavored with either cola or cherry flavor and was carbonated in five-gallon, stainless steel tanks.* The concentration was adjusted so that seven fluid ounces contained the equivalent of 75 gm. of glucose. Using an ordinary drug store type of dispenser, the carbonated drink was rapidly dispensed into calibrated paper cups.

The solution was carbonated and bottled by usual commercial methods into 7-oz. bottles, each of which contained the equivalent of 75 gm. of glucose. Under conditions where it was necessary to hand out the

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*The authors are indebted to the Canada Dry Corporation for the carbonation process.

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loading dose in advance of the testing date, the bottles were quite convenient.*

Another method of dispensing was to prepare a flavored concentrate containing 65 per cent of carbohydrate by weight (84 gm. per 100 ml.). Three fluid ounces of this concentrate (89 ml.) were dispensed into paper cups which were capped with a plastic cover. When the subject was ready to drink the solution the cup was filled to seven ounces (210 ml.) with ice-cold, carbonated water (or ordinary water, or according to taste), mixed and ingested.

This new solution was much less sweet and had a lower osmotic pressure than the glucose solution commonly used for tolerance tests, a factor of primary importance in the prevention of nausea. It was well tolerated even by children and pregnant women. It has now been administered to 50,000 persons with an incidence of nausea of less than 0.1 per cent. Not one person vomited. In a dose of 75 gm. of carbohydrate this new preparation yields blood glucose curves which, for practical purposes, are identical to those obtained after 100 gm. of glucose. Details of these experiments are being published.[3]

No attempt was made to have the subjects in a fasting state at the time of the initial screening period. Hayner et al.[4] have stated that "The administration of a glucose challenge whenever a person comes in for an examination, no matter when or what he has last eaten, appears to be an entirely reasonable method for testing for carbohydrate tolerance." This statement was based on a study in which the challenge was given on a fasting basis and one, two and three hours after a meal. Since all the subjects in a mass survey are essentially ambulatory and actively working, there is very little likelihood of a "starvation" type of glucose tolerance curve.

Two hours after drinking the "CL" solution, the patient presented himself for finger blood testing. It was determined arbitrarily to run the screening finger blood procedure two hours after the ingestion of "CL."

Blood glucose analyses were performed on capillary blood by a ferricyanide reduction method, using a modified AutoAnalyzer (Technicon Company). The modifications did not change the principle of the method or equipment but merely decreased the size of the components so that the apparatus was portable. Briefly, the changes were as follows: The sample changer used a solenoid, rather than a lifting arm, to switch the sample tube from one cup to another. The chain-proportioning pump was replaced with a DeBakey type roller pump.[5] The dialyzer which contained the surface area of cellophane equivalent to the double dialyzer of the Technicon unit was made of lucite and was not placed in a constant temperature bath. The glass heating coil was kept at 95° C. with an aluminum block heater that did not require a stirring motor. All the above components were contained in one module 13-in. by 10-in. by 9-in.

The continuous flow colorimeter utilized a microscope lamp as a light source and an unbreakable plastic flow cell. The output from the colorimeter was fed to a Leeds and Northrup Speedomax H portable recorder that had been modified for radio recording. The equipment was described in a preliminary abstract.[6]

A "finger warmer" was developed which consists of an electrically heated aluminum block which accommodates and heats the finger to be pricked and thus facilitates the blood availability in cold weather.

In actual practice .075 ml. of finger blood was drawn into a disposable but accurate capillary micro pipette* and diluted with 1.2 ml. of a 1 per cent solution of sodium fluoride in a plastic vial that fitted into the sample plate of the glucose analyzer. Results were available seven minutes later. Each machine analyzes forty samples per hour.

There was no attempt to keep the subjects inactive during the two-hour interval between the ingestion of the "CL" and the capillary blood test.

Figure 1 shows results from seventeen diabetic subjects with an average fasting blood glucose of 80 mg. per 100 ml. and the subsequent blood glucose curves comparing the "CL" load and the 100-gm. glucose load.

COMMUNITY MOBILIZATION AND PATIENT PROCUREMENT

The success of a screening program depends upon the cooperation of the community. Two examples of the testing program are as follows:

1. *Industrial program*

Cooperation of industry was achieved by acquainting a top official in a company with the program. Business leaders were very conscious of the possible benefits to their employees and, therefore, were most enthusiastic in supporting this project. A meeting was arranged with a representative from the testing program, the personnel officer, a representative from labor and the plant physician. Exact dates were arranged and literature

*In this form the solution is now commercially available—Glucola, Ames Company, Elkhart, Indiana.

*Micro-Caps, Drummond Scientific Corp., Broomall, Pennsylvania.

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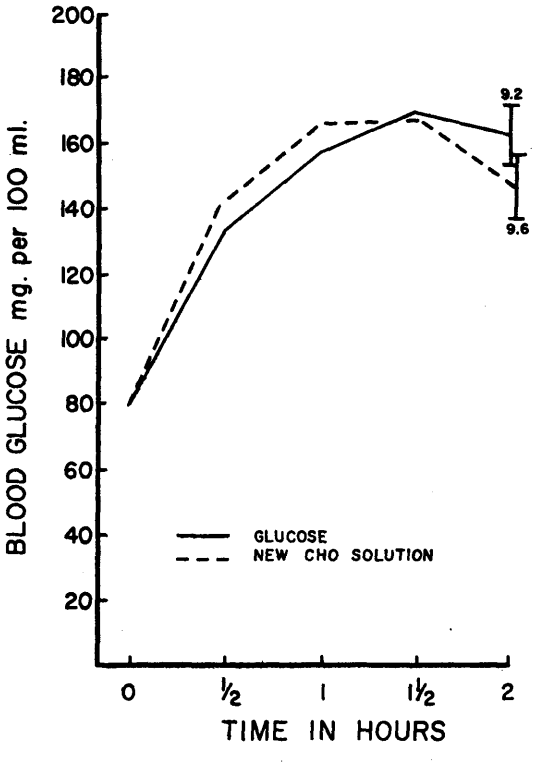

FIGURE 1

publicizing the program was distributed for posting. In some cases a letter was sent to each employee of the company.

After the scheduling was completed, a fact card was filled out by the screenee. Permission was asked to notify his physician of the results on the same card.

The "loading" program was carried out in a variety of ways. In some areas, the individual was given his "CL" when he arrived at work and was asked to drink it at a certain time and to report for his finger blood testing two hours later. Other subjects obtained their "CL" from a dispensing station and then returned to this same location two hours later for their blood test.

The main objective was to have the screenee lose as little time as possible from work. It was found to be more time-saving and convenient to collect the blood samples and transport them to a central laboratory to analyze. Time lost from work was gradually decreased from twenty minutes to as little as five minutes per individual.

Notification of a positive test was done by one of two methods. Each was confidential. A pink card was sent by mail to the subject's home informing him of his test results and asking him to report for a confirmatory carbohydrate tolerance test at the Cleveland Diabetes Headquarters. This test consisted of loading the screenee with "CL" solution and obtaining a capillary blood glucose analysis, fasting, and one and two hours after the load. More frequently the patient was called by phone and asked to report.

When the confirmatory carbohydrate tolerance test was completed and found to be abnormal, the screenee's physician was sent the results of the test. The criteria for an abnormal test using this technic were as follows: Fasting level above 120 mg. per 100 ml.; one hour after "CL" load, above 190 mg. per 100 ml.; two hours after, above 140 mg. per 100 ml. Any one of these criteria was considered sufficient evidence to indicate an abnormal test. The confirmatory test was important because it identified the persons with an abnormal glucose tolerance curve with very little chance of error.

The physician was requested to return a very brief questionnaire in which he was asked to confirm the diagnosis, to report physical signs of diabetes, to indicate the treatment instituted, and to add pertinent information which would aid in cataloguing the patient.

2. *Residential program*

The second example of the detection program was neighborhood solicitation on a door-to-door basis to secure persons desirous of being tested for diabetes. This was carried out by groups consisting of Parent-Teacher Associations, Girl Scouts and other clubs. In addition, local poster displays were used. Minimal radio and newspaper publicity was employed. Mobile units were stationed in the vicinity of the schools and also in shopping centers. These methods were not very successful. Better results were obtained by a professional advertising agency which developed a more thorough publicity program using radio, television, posters and newspapers. The daily papers publicized the information by special interest stories and information about the location and schedules of the mobile units. Shopping centers and transportation concentration points were used with great effect. The number of screenees recently exceeded the technical capacity of the project.

Once the residential program was organized, it was very similar to the program in industry except that the headquarters was the mobile unit, or other available space in the area. The mobile units consisted of a converted city transit bus and a thirty-five-foot trailer. These were equipped as complete laboratories and were stationed in the testing areas. When relatively few people were screened, it was convenient to have the

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portable glucose analyzer on the mobile unit so that the screenees could be given their results immediately. The mobile units were excellent for publicity purposes and efficient where relatively small groups were tested, that is, in the magnitude of 1,000 per week, but when more rapid testing was necessary, i.e., 800 per day, the space available was not adequate.

An innovation in the program was recently introduced. The new technic was as follows: A "CL" drink was administered and two hours later a drop of capillary blood was placed on a new paper strip* for the quantitative determination of blood glucose. All those showing blood glucose levels above 120 mg. per 100 ml. were submitted to the automatic glucose analyzer, as before. This reduced the total number of analyzer examinations by about 80 per cent. The paper test could be done in one minute, and prompt notification was possible to all obvious negatives.

Comparative tests using the paper strip and the automatic glucose analyzer were simultaneously run on each of 1,900 samples. The correlation was excellent. Only one sample read under 120 mg. per 100 ml. on the paper strip and over 140 mg. per 100 ml. on the automatic glucose analyzer.

RESULTS AND DISCUSSION

The results of the completed pilot study involving 8,790 people are summarized in table 1.

The figures presented in table 1 are not necessarily representative of the total population because they reflect a motivated group. The group was motivated by the fact it contained many obese persons and many with a family history of diabetes. In table 1, the highest numbers of screenees were in the third and fourth decades of age. This grouping corresponds to the industrial population in which most workers are in these decades. All comparisons between studies must be based on the age of the screenees.

The prevalence of abnormal blood glucose levels increased with each succeeding decade, as would be expected.

Of the 709 positive screenees, 560 had confirmatory glucose tolerance tests done and 407 of the 560 had an abnormal glucose tolerance test by the above-mentioned standards, for a total over-all incidence of 4.5 per cent. In effect, these persons had two abnormal carbohydrate tolerance tests on two separate occasions and for practical purposes are highly suspect of having diabetes.

*Dextrostix, Ames Company, Elkhart, Indiana.

TABLE 1

Comparative results by decades of positive screenees

Age (years)	All subjects	Positive screens*		Positive GTT†		Negative GTT	GTT not done‡
		Number	Per cent	Number	Per cent	Number	Number
10-19	49	—	—	—	—	—	—
20-29	917	15	2.0	5	0.5	6	4
30-39	2,285	77	3.5	23	1.0	34	20
40-49	2,852	164	6.0	83	3.0	48	33
50-59	1,671	181	18.0	108	6.5	33	36
60-69	741	176	23.5	118	16.0	28	32
70-79	228	74	32.5	50	22.0	4	22
80-89	40	18	45.0	16	40.0	0	2
90-99	7	4	57.0	4	57.0	0	0
Totals	8,790	709	8.0	407	4.5	153	149

*Positive screens—Subjects with a blood glucose above 140 mg. per 100 ml. two hours after "CL" load.

†Positive GTT—Subjects with any one finger blood glucose level above the accepted normal. Fasting 120; 1 hr 190; 2 hr. 140.

‡GTT not done—Screenees did not appear for confirmatory glucose tolerance test.

A discrepancy between the initial positive screening test and the subsequent normal carbohydrate tolerance test, when present, might be explained in some instances by the fact the subject had eaten between the "CL" load and finger blood testing. This was unlikely with the second test because the patients were under observation. Another possible explanation is the intra individual variation, as others have reported.[7]

The heading, "Glucose Tolerance Tests Not Done," table 1, included patients desiring to go directly to their family doctors for confirmatory testing.

In 1961, a careful statistical survey was conducted by the Research Department of The Welfare Federation of Cleveland for the Diabetes Association of Greater Cleveland, in which the distribution, utilization and results of the use of paper glucose oxidase tests on random urine samples were studied in the City of South Euclid, Ohio.[8] Results are compared with the current program in table 2. These figures show twelve times as many people identified with the Finger Blood Study, and since each study attempted to exclude known diabetes, this comparison is most convincing. The age of the population tested is shown in table 2. Furthermore, the glucose oxidase tests on urine can ascertain only overt diabetes, whereas the blood glucose method is capable of finding latent diabetes.

It should be emphasized that this method is still in the experimental stage and is not yet ready for general use throughout the country. The preparation and di

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TABLE 2

Comparison of South Euclid testing programs

	Urine test (glucose oxidase)	Finger blood test
Total screened	802	3,810
Positive screens	8	450
GTT done	5	382
GTT positive	4	242
Final positive (per cent)	0.5	6

Age distribution in samples

Age (years)	Urine test (per cent)	Finger blood test (per cent)
1-20	27	.5
20-50	42	68
50-80	30	30

tribution of the carbonated drink requires facilities not generally available to local or state health departments. The initial cost of the mobile unit is high. Remodeling and maintenance is also an expensive item. The operation and maintenance of the automatic glucose analyzer requires trained and skilled technicians. The volunteer services of large numbers of capable and dedicated individuals are necessary.

It is hoped that the use of paper strips for blood glucose analysis, now being evaluated, will make this screening method more widely applicable and less expensive.

ACKNOWLEDGMENT

This study was supported by Grant CH-37-9A63, United States Public Health Service, and by the Fund for the Study of Diabetes and Related Metabolic Diseases at Western Reserve University.

REFERENCES

[1] Allan, F. N., and Georgeson, L. W.: A candy tolerance test in the detection of early diabetes. Med. Clin. N. Amer. *44*:429-32, 1960.

[2] Leonards, J. R., and Free, A. H.: Note on gastric retention in one-hour and two-hour glucose tolerance tests. J. Lab. Clin. Med. 30:1070-71, 1945.

[3] Leonards, J. R., McCullagh, E. P., and Christopher, T. C.: A new carbohydrate solution for testing glucose tolerance. Diabetes. *14*:96-99, Feb. 1965.

[4] Hayner, Norman S. et al.: The One-hour Oral Glucose Tolerance Test. National Center for Health Statistics, Series 2, No. 3, U. S. Department of Health, Education, and Welfare and U. S. Public Health Service.

[5] DeBakey, M.: Simple continuous flow blood transfusion instrument. New Orleans Med. Surg. J. 87:386, 1934.

[6] Leonards, J. R.: A portable automatic instrument for the rapid determination of blood glucose concentration. Abstracts. American Diabetes Association, p. 58, 1961.

[7] West, K. M., Wulff, J. A., Reigel, D. G., and Fitzgerald, D. T.: Oral carbohydrate tolerance test. Arch. Intern. Med. *113*:5, May 1964.

[8] Research Department, The Welfare Federation of Cleveland: The Relative Effectiveness of Several Methods of Distribution of Clinistix Kits for the Self Detection of Diabetes. Survey, 1962.

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