An Evaluation of Patient Performance of and Their Satisfaction with Various Rapid Blood Glucose Measurement Systems

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We evaluated the performance of 50 insulin-dependent diabetic patients in the measurement of their own capillary blood glucose concentrations using Chemstrip bG, Dextrostix-Dextrometer, and StatTek systems. With all systems, patient performance was suboptimal when compared with the accuracy of paramedical personnel. The percentage of patient determinations that differed from the laboratory value by more than 20% was 37%, 30%, and 14% for the Chemstrip bG, Dextrostix-Dextrometer, and StatTek systems, respectively. Only 39 of the patients (78%) could perform accurately with any system. Youth, lack of a higher education, and lower income status contributed significantly to the patients' inaccuracy with the Chemstrip bG technique, whereas these factors had no effect on patient performance with the reflectance meter techniques. Nearly all of the patients were enthusiastic about the value of home glucose monitoring as a means to assess their glycemic control. However, only 30% of the patients selected for home use a technique at which they were suitably adept. In part, this selection error appeared to be due to the greater cost and inconvenience of the reflectance meter techniques compared with the Chemstrip bG technique. These data indicate that unless proper instruction is provided, home glucose monitoring should only be used by a fraction of insulin-requiring diabetic patients and the choice of a particular system for use by an individual patient should be predicated upon his or her demonstrated proficiency with that system. DIABETES CARE 6: 45–49, JANUARY–FEBRUARY 1983.

The recent recognition that normalization of the blood glucose concentration of the insulin-dependent diabetic patient may delay or prevent the development of certain diabetic complications has led to the development of various techniques by which this goal can be approached.[1,2] It is now very clear that the measurement of urinary glucose excretion does not provide any information concerning the antecedent or current blood glucose concentration.[3,4] Thus, increasing attention has been directed toward the development and assessment of methods by which diabetic patients could monitor their own blood glucose concentrations during their normal life situations and alter their insulin dosage accordingly to achieve optimal glycemic control.[2,5,6]

Virtually all of the systems that have been developed for the self-monitoring of blood glucose concentrations have been shown to be remarkably accurate when performed by trained medical or paramedical personnel. Thus, we have previously observed that the estimates of blood glucose concentration were in error by more than 20% (compared with the laboratory serum glucose values) in less than 11% of the determinations performed by registered nurses or physicians using the Chemstrip bG or the Dextrostix-Eyetone systems.[7] Similar accuracy has been demonstrated by others, when these systems as well as the Dextrostix-Dextrometer, StatTek, or Glucochek methods are performed by physicians or nurses.[6,8–10] However, surprisingly little concern has been directed toward the assessment of patient performance with these techniques. If one critically examines the figures provided by various groups of authors, it becomes immediately apparent that patient performance with the various rapid blood glucose measurement techniques is consistently worse than that of medical personnel. For example, in the study of Jovanovic and Peterson, 31% of the determinations performed by their pregnant diabetic patients using the Dextrostix-Eyetone technique were in error by more than 20%.[11] Similarly, six studies of the performance of patients with Chemstrip bG have demonstrated that more than 1/3 of all

determinations were in error by more than 20%. (Mean number of determinations in error was 36.4 ± 3.0%.[8,12–16]) The only exception to the uniformly bad performance of patient measurement of their own blood glucose was the report by Ikeda et al. in which eight patients performed blood glucose determinations using the Dextrostix-Eyetone system with an error rate of only 4%.[17]

If one assumes that an error of blood glucose determination of more than 20% could lead to inappropriate adjustment of insulin dosage, it is obvious that an error rate of 33% in the performance of patients with the currently available rapid glucose measurement techniques is unacceptable. For this reason, we have studied the factors responsible for variations in patient performance with three rapid glucose measurement methods. The influence of factors such as prior experience with glucose monitoring systems, visual acuity, color blindness, age, sex, educational level, and income bracket on the patient performance of each of the techniques was assessed. In addition, we evaluated the patient's conception of the accuracy of the various systems, as well as their preference as to which system they would choose for home glucose monitoring.

METHODS

Study populations. Fifty-one patients who were consecutively admitted to the Diabetes Hospital for adjustment of their insulin therapy were recruited into this study. All provided informed consent. Groups of three patients were randomly assigned to the performance of the three rapid glucose measurement techniques under evaluation.

Six staff registered nurses of the Diabetes Hospital also performed blood glucose measurements with the three rapid glucose measurement systems. All of these nurses were experienced and familiar with the use of the three systems and thus served as a paramedical group against which the patients' performance could be compared.

Patient evaluation. Prior to performance of the blood glucose measurements, all patients were asked to provide information concerning their educational level, income bracket, occupation, and prior experience with rapid glucose monitoring systems. Visual acuity (corrected) was estimated with the use of a Snellen chart. Color vision was evaluated with the Farnsworth D-15 test.[18]

Study design. The patients were instructed in the technique of obtaining capillary blood with an Autolet (Ulster Scientific, Inc., Highland, New York). They were also instructed in the use of the Dextrostix-Dextrometer (Ames Division, Miles Laboratory, Elkhart), Chemstrip bG (with interpolation between the color blocks), and StatTek Systems (Bio-Dynamics/bmc, Indianapolis). All but one patient (whose visual acuity was less than 20/80) demonstrated their proficiency with the three systems to a registered nurse (P.K.F.) before the actual performance of the study. The visually impaired patient had equal difficulty with all systems and was therefore excluded from the study.

During the 3 days that each patient was involved in this study, venous blood was obtained for serum glucose determination by the AutoAnalyzer technique at 0700, 1100, 1500, and 2100 h (as required for the adjustment of their insulin dosage schedule). Within 2 min of each venipuncture, each patient obtained a drop of capillary blood and performed a blood glucose determination by one of the three rapid techniques. Each patient used a single technique for 1 day (i.e., four determinations using each system) and moved on to the other techniques on the following 2 days. The reflectance meters were calibrated by the patients once a day. Objectivity was achieved by the fact that the patients recorded their blood glucose estimates prior to the time that the serum glucose values were reported back by the Clinical Laboratory.

As a result of the study design, each patient was intended to perform four blood glucose determinations with each system. However, due to such phenomena as early discharge from hospital, laboratory errors, conflicting procedures, and reflectance meter eccentricities, the actual number of determinations performed was somewhat less. The correlation between the results obtained with the various systems and the serum glucose concentration measured by the AutoAnalyzer technique was determined by the least-squares technique. An error in the value obtained by a rapid glucose measurement system was defined as a number that differed from the AutoAnalyzer determination by more than 20%. The performance of the nurses, patients, and subsets of patients was assessed by analysis of the percentages of determinations that were in error as well as calculation of the overall percentage error for each group. All values are expressed as the means and standard errors of the mean and statistical analysis of the data used the two-tailed Student's *t* test.

After the performance of the study, the patients were questioned concerning their concept of the value of home glucose monitoring, the relative accuracy of the three systems, and their preference as to which system they would choose to use at home.

RESULTS

The mean age of the 50 patients included in this study was 36.2 ± 2.1 yr (range 11–70 yr), and the group consisted of 26 women and 24 men. The duration of recognized diabetes mellitus was 8.6 ± 1.4 yr and they had been receiving insulin injections for 7.6 ± 1.4 yr. Eighteen of the patients had had prior experience with a rapid glucose measurement system (six with Dextrostix, two with Dextrostix-Eyetone, three with Dextrostix-Dextrometer, and seven with Chemstrips). The serum glucose values obtained during this study ranged from 37 to 668 mg/dl and thus span the range of values that would be encountered by a diabetic patient during his or her daily life.

The breakdown of patients according to age, visual acuity, years of formal education, and family income is shown in Table 1. The majority of the patients were in the younger age group, had excellent visual acuity, had had more than 12 yr of formal education, and had family incomes of more

TABLE 1
Number of patients classified according to age, visual acuity, years of formal education, and income

Age	<30 yr	30 <50 yr	≥50 yr
N (%)	21 (42%)	16 (32%)	13 (26%)
Visual acuity	20/20	>20/20 <20/40	≥20/40 <20/80
N (%)	28 (56%)	14 (28%)	8 (16%)
Years of education	<12 yr	12 <16 yr	≥16 yr
N (%)	13 (26%)	27 (54%)	10 (20%)
Family income	<$10K	>$10K <$20K	>$20K
N (%)	11 (22%)	20 (40%)	19 (38%)

than $10,000. Of the patients under the age of 30 and with less than 12 yr of formal education, six were currently attending school. However, since the current attendance at a school was found to have no influence on any of the results, the students' results were included in all of the data analysis. Similarly, since the two men who were found to be visually dichromatic performed as well as their peers in all of the rapid glucose measurement techniques, their results were included in the data analysis.

The overall performance of nurses and patients with the various techniques is shown in Table 2. It is obvious that the patients' performance of all of the techniques was inferior to that of the nurses. While there was no statistical difference between the performance of the Chemstrip bG and the Dextrostix-Dextrometer techniques by the patients, they were considerably more accurate with the StatTek method (P versus both Chemstrip bG and Dextrostix-Dextrometer <0.001). The patient errors were not the consequence of the recognized capillary-venous glucose gradient since two-thirds of the errors with each rapid glucose measurement technique were on the low side.[19]

Of interest was the fact that neither prior experience, sex, nor visual acuity (when better than 20/80) had any influence on patient performance of any of the techniques. In contrast, as shown in Figure 1, age, income, and years of formal education profoundly influenced the patients' accuracy with Chemstrip bG. Thus, those patients who were under the age of thirty, had an annual family income of less than $10,000, and did not have a college degree performed remarkably poorly with this technique. The percentage of determinations in error by this group was 78%, compared with an 11% error rate by patients over the age of 30 whose annual income was greater than $10,000 and who had a college degree. The effect of age upon accuracy of capillary blood glucose determination was not the consequence of wider fluctuations in the serum glucose concentrations in the younger patients, since the range of serum glucose values as well as the mean serum glucose were similar in all three age groups.

In contrast, neither age nor educational status had any influence on patient performance with the two reflectance meter techniques. Patients whose income was between $10,000 and $20,000 per year performed somewhat better with the Dextrostix-Dextrometer than did patients with either lower or higher incomes (P versus both groups <0.05). Income did not influence patient performance with the StatTek system.

When asked whether they believed that rapid glucose measurement would be more useful than urine glucose testing

TABLE 2
Accuracy of registered nurses and diabetic patients in the performance of capillary blood glucose determinations using three techniques

Study groups	Analytical method		
	Chemstrip bG	Dextrostix-Dextrometer	StatTek
Registered nurses (33 determinations)			
Correlation coefficient	0.966	0.904	0.963
% of determinations in error by >20%	10.7%	21.2%	6.1%
Patients (174 determinations)			
Correlation coefficient	0.811	0.889	0.890
% of determinations in error by >20%	36.8%	29.5%	14.1%

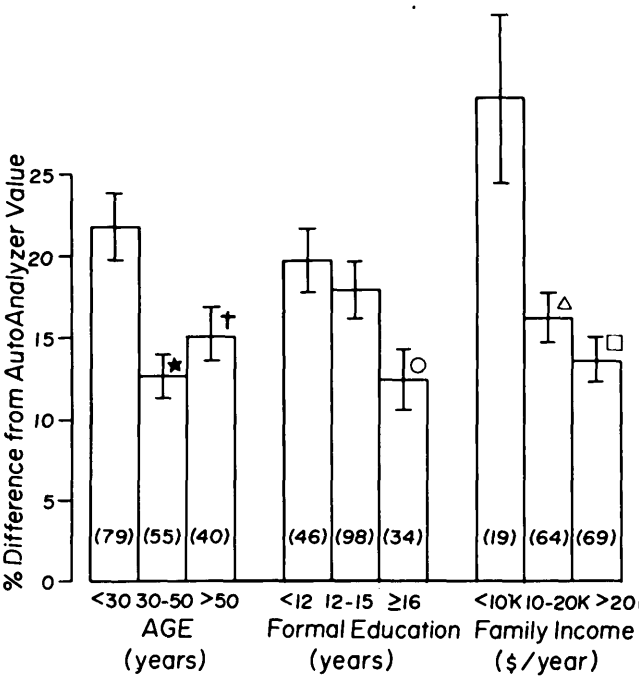

*FIG. 1. Effect of age, education, and income on the mean percentage variation of blood glucose determinations by Chemstrip bG from the serum glucose value obtained by AutoAnalyzer. The bars represent the mean value for each group and the vertical lines represent the standard errors of the means. The number of determinations is given in the parentheses. The symbols represent the following P values: * <0.01 and + <0.025 versus patients younger than 30 yr; ○ <0.01 versus patients with less than 16 yr of formal education; and △ <0.05 and □ <0.01 versus patients whose annual family income was less than $10,000.*

in judging the control of their diabetes, 47 patients responded affirmatively, 1 patient preferred to use both methods, 1 patient did not know, and 1 patient (an 11-yr-old girl) responded negatively. The patients' concept of which system was more accurate and their preference as to which system they would choose to use at home is given in tabular form in Table 3. More than half of the patients expressed a preference for the use of a technique involving a reflectance meter if cost were not a factor. This preference was not influenced if the cost differential of the technique involving a meter was less than $100, but was markedly influenced if the cost differential was greater than $300. Under the latter circumstance, 56% of those patients who would have preferred to use a reflectance meter technique opted for the Chemstrip bG technique instead.

DISCUSSION

The results of this study confirm the previous reports that the accuracy with which patients are able to measure their own blood glucose concentrations using various rapid glucose measurement techniques is unacceptably poor. The patient inaccuracy of approximately 1/3 of determinations with the Chemstrip bG or Dextrostix-Dextrometer techniques suggests that these systems would not permit a sufficiently accurate estimate of the blood glucose concentration to allow the rational adjustment of insulin therapy in most diabetic patients. In contrast, the error rate with the StatTek system appears to be sufficiently low (14%) to permit most patients to use this system to monitor their blood glucose concentrations and to adjust their insulin dosages accordingly.

With regard to patient accuracy with Chemstrip bG, much of the inaccuracy could be accounted for by youth, low income, and lack of a higher education, since when these factors were not present, the error rate was decreased to an acceptably low level (11%) to be clinically useful. Similarly, 17 of the 50 patients performed all determinations with the Dextrostix-Dextrometer within the acceptable range of within 20% of the control value.

Thus, although the data support the patients' concept that the StatTek system is somewhat more accurate than the other two systems under evaluation, it does not indicate that the StatTek should be indiscriminately recommended for use in home glucose monitoring. In fact, since 22 of the 50 patients were in error with their StatTek determinations, it would be inappropriate to recommend its use by those particular patients.

TABLE 3

Patient concept of which rapid glucose measurement system was most accurate and their preference for the system they would choose to use at home

	Chemstrip bG	Dextrostix-Dextrometer	StatTek
Most accurate system	26%	34%	40%
System preferred for home use (if cost were not a factor)	45%	31%	24%
System preferred if the reflectance meter costs less than $100.00	50%	25%	25%
System preferred if the reflectance meter costs more than $300.00	77%	13%	10%

The fact that various factors including age, income, and education can influence patient performance with the various techniques suggests that the only way that one can decide upon the appropriate home glucose monitoring system for the individual patient is to have that patient demonstrate and document his accuracy with that system. If we were to apply that criterion to the 50 patients involved in the present study, we could recommend the use of Chemstrip bG to 11, Dextrostix-Dextrometer to 14, StatTek to 21, and would suggest to 16 patients that they receive further training to improve their technique or that they should await the perfection of more foolproof glucose measurement systems before they embark on home glucose monitoring.

However, the tailoring of a home glucose monitoring system for a particular patient cannot be based solely on patient performance. Certain patients will be either unwilling or unable to afford the cost of a system with which they can perform accurately. Other patients may object to the technical requirements for the calibration and use of a reflectance meter. In this regard, it is of interest that of the 34 patients in this study who could perform at least one of the techniques accurately, only 15 (44%) chose the correct method for home use. Of the 19 incorrect choices, 12 were due to a preference for Chemstrip bG over the reflectance meter techniques. When the financial aspect of the purchase of a reflectance meter was considered, an additional four patients chose to use a technique at which they were inaccurate (but this also caused an equal number of patients to change from an inaccurate to a more accurate technique).

The caveat that the choice of a home glucose monitoring system should be based not only on patient performance but also on patient preference has been raised before and is supported by the present study.[12] The observation that only 68% of the patients involved in this study could perform at least one of the three techniques accurately and that only 30% of the patients chose a technique at which they were accurate has important implications. An error of more than 20% in the blood glucose concentration could lead to an inappropriate alteration of insulin therapy by the patient who uses an algorithm for the adjustment of his or her insulin dosage.[6] This problem is further highlighted by the fact that when the accuracy of the present group of patients with their preferred home glucose monitoring system was assessed, 30% of their determinations were in error (range 20.4% to 115.7% in error). We conclude that home glucose monitoring is not the be-all and end-all that it has been claimed to be,[9,20,21] and that careful assessment of patient performance with the various available systems must be carried out before deciding whether a particular patient should monitor his or her own blood glucose, and if so, which system should be employed.

The indiscriminate prescription of any given home glucose monitoring system to a diabetic patient is likely to do that patient as much harm as it does good.

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