# A Comparative Study of Blood Glucose Test Strips

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Blood glucose test strips provide a convenient and rapid method for estimation of blood glucose. They can be read either by eye against a color scale or in a reflectance meter. This study compares the performance characteristics of the principal test strips available. When read visually, the BM Glycemie 20–800 (Chemstrip bG) strip was shown to be more accurate than the Dextrostix strip. Comparison of the meter systems showed Reflotest-Glucose to be more accurate and precise than Dextrostix. This was because the Reflotest system was read closer to the endpoint of color development and because there was less subsequent color fade than with the Dextrostix system. Reflotest-Glucose and Reflotest-Hypoglycemie developed colors that were stable for at least 2 days after completion of the test. However, when using a reflectance meter the Reflotest system required two strips to cover the important range of blood glucose.
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The importance of good control of blood glucose in diabetes is accepted.[1,2] As a result of the acknowledged inaccuracies of monitoring control using urine tests, there has been increasing interest in the use of systems for home monitoring of blood glucose in patients with insulin-dependent diabetes.[3–5] The performance characteristics of the various reflectance meters available for measuring blood glucose using reagent strips have been described,[6] but no studies are available providing similar information on the strips themselves.

There are at present two principal glucose reagent strip systems available—Dextrostix and Reflotest. The Dextrostix system comprises a single strip. The Reflotest system, however, includes Reflotest-Glucose and Reflotest-Hypoglycemie, for meter-read blood glucose in the normal to high ranges and the low ranges, respectively. More recently, BM Glycemie 20–800 (Chemstrip bG in the United States) has been introduced for visually read blood glucose estimation over both ranges.

The aims of the present study were to compare the precision, reliability, and problems of the presently available test strips.

## MATERIALS, METHODS AND RESULTS

Commercially available reagent strips were used throughout the study. Dextrostix were obtained from Ames Company, Division of Miles Laboratories Ltd. (Slough, England). Reflotest and BM Glycemie 20–800 strips were obtained from Boehringer Corporation Ltd. (London). Care was taken when using Dextrostix to use either the foil-wrapped packs or a previously unopened bottle. The manufacturers' instructions were followed closely.

Three of the meters used were standard production models—Dextrostix-Eyetone (Ames), Reflomat (Boehringer), and Glucochek (Medistron Ltd., Alpine Works, United Kingdom). The fourth meter was one of a series of Glucochek meters that had been modified to read Reflotest strips instead of Dextrostix. The use of appropriately calibrated Glucochek meters allowed direct comparison of the precision of Dextrostix and Reflotest.

Whole blood glucose was analyzed in the laboratory, when appropriate, using a standard automated glucose-oxidase method.

The hospital staff involved in assessment of the strips consisted of one doctor and one experienced laboratory technician.

Correlations were sought using linear regression analysis. Student's $t$ test was used when appropriate.

*Visual performance of Dextrostix and BM Glycemie 20–800.* Five subjects (four patients and one doctor), aged between 16 and 32 yr, carried out sequential estimations on blood samples read visually against the manufacturers' color scale using Dextrostix and BM Glycemie 20–800. Samples from

normal and diabetic subjects were placed into lithium-heparin containers. Aliquots of whole blood were then drawn into five 2-ml syringes and each individual placed blood onto the strips in turn. For any one sample, estimation of the blood glucose on one strip system was followed immediately by an estimation on the alternative system. The order for reading Dextrostix and Reflotest was alternated for each blood sample. After the use of the second strip, the remainder of the aliquot was placed into fluoride-oxalate to arrest glycolysis and allow subsequent analysis in the laboratory. The negligible effect of glycolysis over this 3-min period enabled direct comparison of the results obtained using Dextrostix and BM Glycemie 20–800 with laboratory results. The subjects were unaware of the results obtained by other individuals until completion of the study. One patient had had prior experience with the visual reading of Dextrostix; none of the patients had previously used BM Glycemie 20–800. The results are shown in Figure 1.

It can be seen that using Dextrostix there was a marked tendency for underestimation of blood glucose concentration when the laboratory value was greater than 10 mmol/L. This underestimation was much less marked using BM Glycemie 20–800. In practice, accuracy is most important for values below about 10 mmol/L, and so the performance of the two systems within this range was assessed in greater detail. For values of less than 10 mmol/L (as read on the strip) all results obtained with BM Glycemie 20–800 were within 2 mmol/L of the laboratory reading, but, using Dextrostix, 21% of readings exceeded this limit.

For the same range of blood glucose the differences from autoanalyzer values were calculated and the mean difference from autoanalyzer determined for each of the two strip systems. The mean difference ± SEM from the laboratory was 1.19 ± 0.14 mmol/L (N = 48) and 0.82 ± 0.08 mmol/L (N = 43) for Dextrostix and BM Glycemie, respectively ($P < 0.05$ between the two strips).

Defects in color vision could lead to difficulties in interpretation of the reagent strip. Figure 2 illustrates the correlation obtained between visual readings of BM Glycemie 20–800 and laboratory values for one patient who was known to be red-green color blind.

*Accuracy of Reflotest and Dextrostix using meters.* Two members of the hospital staff made an assessment of the accuracy of Dextrostix and Reflotest-Glucose strips using the Eyetone and Reflomat meters, respectively. The blood glucose values obtained by reflectance meter and in the laboratory on the same samples are shown in Figure 3 (A and B). When compared with the laboratory, both systems showed satisfactory slopes, intercepts, and correlation coefficients. However, more scatter occurred with Dextrostix than with Reflotest; this was particularly evident at the higher levels of blood glucose. Over the clinically important range up to 10 mmol/L, the differences between meter reading of Dextrostix and autoanalyzer results were more than 1 mmol/L in 21% and more than 2 mmol/L in 7% of samples, whereas with Reflotest-Glucose over the same range the differences were more than 1 mmol/L in 15% of samples but never more than 2 mmol/L.

For observed values of less than 10 mmol/L, the differences from autoanalyzer blood glucose were calculated and the mean difference from autoanalyzer determined for each of the two strip systems. The mean differences ± SEM for Dextrostix and Reflotest-Glucose were 0.79 ± 0.09 mmol/L (N = 70) and 0.62 ± 0.05 mmol/L (N = 77), respectively. The difference between the means failed to attain signifi-

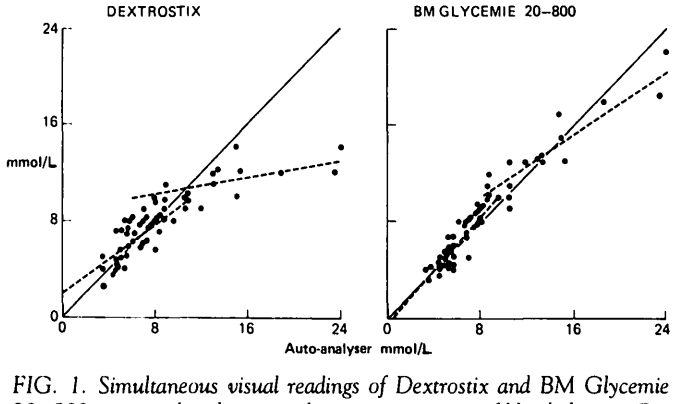


*FIG. 1. Simultaneous visual readings of Dextrostix and BM Glycemie 20–800 compared with autoanalyzer measurement of blood glucose. Regression lines are shown in each case for observed values of less than and greater than 10 mmol/L (---) and ideal correlation (—). (Dextrostix < 10 mmol/L, N = 44, y = 0.71x + 2.13, r = 0.75, P < 0.001; Dextrostix ≥ 10 mmol/L, N = 13, y = 0.18x + 8.99, r = 0.66, P < 0.01; BM 20–800 < 10 mmol/L, N = 40, y = 1.10x − 0.36, r = 0.88, P < 0.001; BM 20–800 ≥ 10 mmol/L, N = 17, y = 0.65x + 4.98, r = 0.94, P < 0.001)*

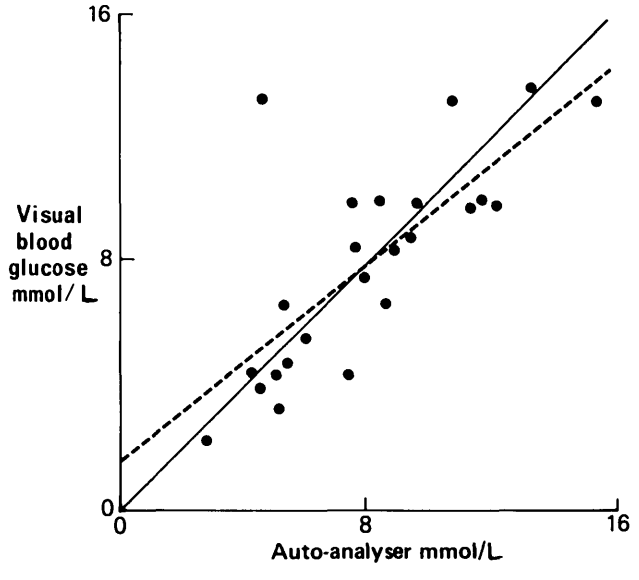


*FIG. 2. Correlation obtained between blood glucose measured visually in a color-blind patient using BM Glycemie (N = 24, y = 0.80x + 1.61, r = 0.76, P < 0.001). Calculated (---) and ideal (—) regression lines are shown.*

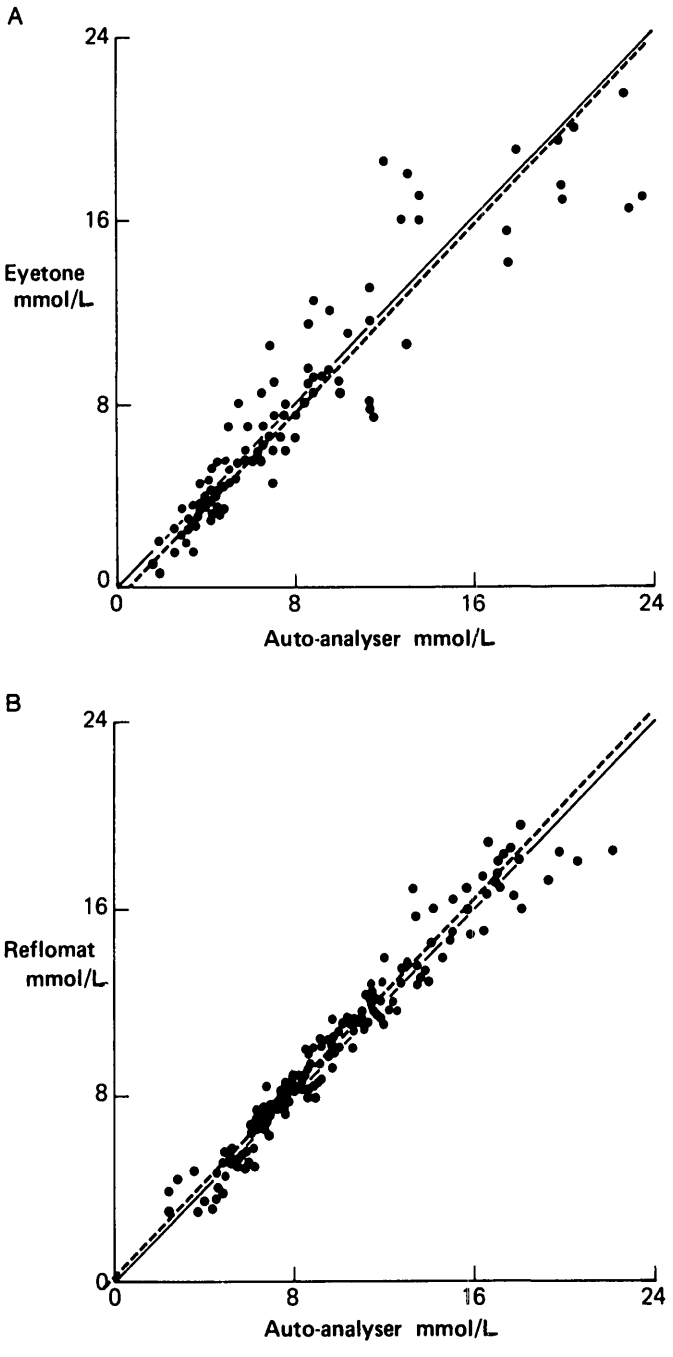


*FIG. 3. (A) Correlation obtained between blood glucose measured using Dextrostix and Eyetone meter versus autoanalyzer ($N = 94$, $y = 1.01x - 0.29$, $r = 0.93$, $P < 0.001$). (B) Correlation obtained between blood glucose measured using Reflotest-Glucose and Reflomat meter versus autoanalyzer ($N = 147$, $y = 1.01x + 0.18$, $r = 0.97$, $P < 0.001$). Calculated (---) and ideal (—) regression lines are shown.*

cance ($0.05 < P < 0.1$), but the larger SEM for Dextrostix confirmed the wider scatter of the results using this strip.

*Precision of Reflotest and Dextrostix using meters.* To compare the precision of Dextrostix and Reflotest-Glucose strips, the variable of the meter had to be eliminated. Two Glucochek meters were therefore used, one calibrated for Dextrostix and one for Reflotest-Glucose. Ten immediately successive complete tests were performed on a "low" sample (blood glucose 4–6 mmol/L) using Reflotest. Overlapping of timing allowed completion of the series within 15 min. Testing was repeated with the same sample over the same time period using Dextrostix. Thus, the minimal effect of glycolysis over this time was similar for both systems. On a second "low" sample, testing of Dextrostix preceded Reflotest. The sequence was repeated for two "high" samples (blood glucose 10–14 mmol/L).

The data obtained were used to calculate coefficients of variation (CV) as shown in Table 1. Using Reflotest-Glucose the CV was equal to or less than 3.0% on all samples, but with Dextrostix the CV was higher, ranging from 3.8% to 11.4%.

*Critical nature of time in reading glucose reagent strips.* Two main errors in timing are possible. The contact time between blood and reagent strip will vary in practice from the recommended 60 s. A series of seven samples were therefore studied using each of the two strips with contact times of 50, 60, and 70 s for each blood sample. Removal of blood from Dextrostix 10 s early and 10 s late resulted in an under-reading of 11.9 ± 2.8% (SEM) and an over-reading of 18.8 ± 3.9%, respectively. Equivalent figures for Reflotest-Glucose were 4.2 ± 0.5% and 2.5 ± 2.5%, respectively.

Secondly, the time at which the strip is actually read may be judged incorrectly. Using Dextrostix, a 10-s or a 20-s delay in reading resulted in underestimates of 6.8 ± 1.5% and 8.7 ± 1.2% ($N = 9$), respectively, whereas the figures for Reflotest-Glucose were 3.9 ± 0.7% and 3.6 ± 0.8% ($N = 9$), respectively.

*Stability of test strip color.* Dextrostix, Reflotest-Glucose, and Reflotest-Hypoglycemie were tested for stability of color after a baseline reading had been taken. Strips were stored at room temperature in dessicant containers and reread after 24 and 48 h. Results are shown in Figure 4. The color faded rapidly with Dextrostix. Both Reflotest systems were relatively stable, apart from the tendency for initially low levels to increase after 24 h with Reflotest-Glucose.

## DISCUSSION

Many of the characteristics of the test strips described above are closely interrelated. Thus, the demonstration of superior

TABLE 1
Assessment of precision of Dextrostix and Reflotest

| | Sample number | Coefficient of variation (%) | |
|---|---|---|---|
| | | Dextrostix | Reflotest |
| "Low" blood glucose | 1 (N=10) | 5.0 | 2.9 |
| | 2 (N=10) | 11.4 | 3.0 |
| "High" blood glucose | 3 (N=10) | 3.8 | 1.6 |
| | 4 (N=10) | 7.9 | 2.4 |

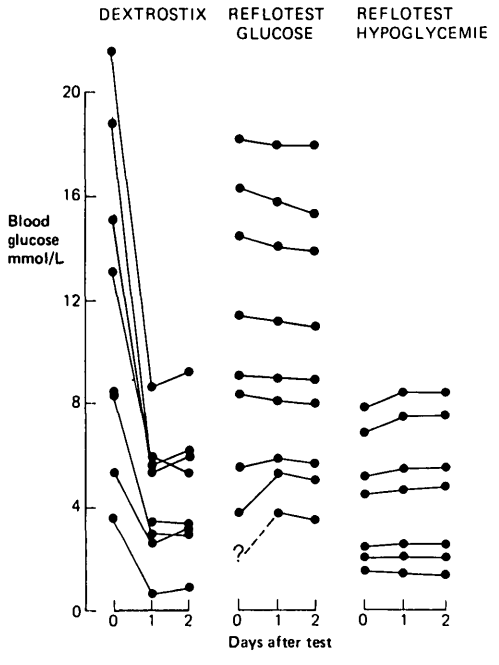


*FIG. 4. Results of reading Dextrostix, Reflotest-Glucose, and Reflotest-Hypoglycemie at the recommended time and after storage for 1 and 2 days in a dessicant container.*

accuracy and precision of Reflotest-Glucose is largely due to the fact that the system is read close to "endpoint" on the color-development curve. As a result, timing inaccuracies occurring when using Reflotest produced a smaller error than when using Dextrostix. Color fade is less using Reflotest, thus further minimizing error. These timing errors are important, particularly as readings will generally be carried out by ward staff or by patients at home with little or no means of assessing the accuracy of the result obtained.

The quality of visual performance of reagent strips is important, since even the cheaper reflectance meters are relatively expensive and can be seriously inaccurate at times.[6] A strip suitable for visual reading would make home blood sampling available to a larger number of diabetic subjects than if a meter was essential. Our results indicate that BM Glycemie 20–800 is more suitable than Dextrostix for this purpose. Furthermore, apart from one value that was markedly different from a subsequent laboratory result, the BM Glycemie 20–800 strip was satisfactory when used by our one color-blind patient.

Howe-Davies and her colleagues demonstrated the stability of Reflotest strips stored over several days.[7] We have found this to be clinically useful, but difficulty can occur at lower levels of blood glucose because of the tendency for hypoglycemic samples to be over-read when checked 24 h or more after the blood has been removed from Reflotest-Glucose. We have shown in this study that the Reflotest-Hypoglycemie strip is stable under these conditions and can therefore be used to complement the standard Reflotest strip in this range.

Assessment of the convenience of reagent strips is necessarily very subjective. However, the smaller square on the Reflotest strip was easier to cover evenly with a drop of blood —an important point in obtaining accurate results. Our patients found it much more convenient to remove the blood from the strip by wiping the blood off, as on Reflotest, than by washing, as on Dextrostix. The dessicant in the container is important for the preservation of both strips; it is virtually impossible to "lose" the dessicant in the Reflotest container, since it is incorporated into the lid of the container, whereas the dessicant bag in the Dextrostix bottle is easily removed or lost. Use of foil-wrapped Dextrostix to overcome this difficulty doubles the price of each test at current prices. A minor advantage of Dextrostix is that the test procedure takes only 1 min, against 2 min for Reflotest. When used with a meter, the Dextrostix system has one important advantage over Reflotest-Glucose in that it is capable of reading blood glucose levels of less than 3 mmol/L on the standard strip. Accurate reading in this range with Reflotest necessitates repetition of the test using Reflotest-Hypoglycemie, thus adding 2 min to the length of time required to obtain a result and doubling the cost of the test. This does not apply to the visually read system. On the contrary, visual reading of BM Glycemie 20–800 is at least as good as Dextrostix at the lower end of the range and certainly better at higher levels of blood glucose.

In conclusion, the results of this study indicate that the overall performance of both the Reflotest-Glucose and the BM Glycemie 20–800 test strips are superior to the Dextrostix system for routine use. We would recommend the use of BM Glycemie 20–800, since it is simpler and cheaper than the use of meters and provides satisfactory accuracy for day-to-day use by patients at home.

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