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Laboratory assessment of three glucometers

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Summary

The study was designed to assess the technical performance of three common glucometers (Glucometer Elite, Accutrend Alpha, One Touch Basic) marketed in Nigeria. This is with a view to assessing their suitability for use in this environment and to provide an informed opinion on the selection option. Venous blood, capillary blood, serum and plasma were assayed during the study. Precision, accuracy, linearity and effect of haemolysis and haematocrit were carried out on each glucometer. Simultaneous analysis using the laboratory reference method was also carried out where necessary. Intra-assay precision was between 1.4%(Glucometer Elite) - 11% (One Touch Basic) while the interassay precision was best for the Accutrend Alpha with a CV of 1.9%. All three glucometers correlated excellently with laboratory values and the %deviation from laboratory values was 0.2-10.5%. The Glucometer Elite was the most portable and used the least volume of blood (5ul). One Touch Basic Glucometer was the least affected by haemolysis. Haematocrit values less than 50% did not have any effect on the three glucometer readings. The technical performance of these three glucometers were found to be acceptable and are recommended for use by diabetic patients, emergency and intensive care units and antenatal clinics, subject to periodic assessment and calibration.

Keywords: *Glucometer, haemolysis, haematocrit, interassay, Accutrend Alpha*

Résumé

Une étude était désigné pour évaluer la performance technique de 3 glucomètres commun (glucomètre Elite , AccuTrend Alpha, One Touch Basic) vendus au Nigéria. Ceci avait pour but d'évaluer leur utilisation effective dans cette environnement et apporter une opinion juste sur le choix d'option. Le sang veineux capillaire, le serum et le plasma étaient examinés. La précision, l'exactitude, la linéarité, l'effet d'hémolyse et l' hémocrite étaient mesurés utilisant chacun des glucomètres. Simultanément, la méthode laboratoire de référence était faite si nécessaire. L'intraprecision était entre 1.4%(G.E), 11% (O T Basic) lorsque l' intraprecision du l'accutrend Alpha était meilleur avec un CV de 1.9 %. Tous les 3 glucomètres, il avait une corrélation excellente entre les 3 glucomètres et les valeurs du laboratoires avec une pourcentage de déviation entre 0.,2 -10.5%. Le glucomètre Elite était le plus portable et utilisant moins de volume du sang (5 ul). Le glucomètre : One Touch Basic était le moins affecté par l'hématologie et les valeurs de l'hématocrite moins de 50% n' avaient aucun effet sur la lecture des 3 glucomètres. La performance technique de ces 3 glucomètres étaient acceptable et sont recommandés pour

utilisation sur les patients diabétiques dans les unités d'urgence et soins intensive et prénatales , ayant besoin une maintenance contrôle périodique et calibration.

Introduction

The care of diabetic patients has undergone several changes in recent times. The use of self-monitoring devices (glucometers) has completely revolutionized the management of diabetes mellitus.

Glucometers were introduced in 1978 [1] and now several versions have appeared in the markets and are claimed to be reliable. In some of the UK Health Trust, three times as many blood glucose measurements in patients are carried out outside the laboratory [2]. In the United States virtually all diabetic patients have blood glucometers [2].

In Nigeria however these glucometers are not yet within the reach of most patients due to the socio-economic problems, they are nevertheless available to those patients in the upper socioeconomic class. Apart from the fast turnaround time of less than one minute, the glucometers only need small quantities of blood for analysis and are generally user friendly. This is of tremendous importance in obese and paediatric patients where phlebotomy may be difficult. A clinician also needs such an instrument for optimum insulin regimens and monitoring of patients in intensive care units or in emergency cases. It has become necessary therefore to evaluate the technical performances of some glucometers available in the Nigerian environment. The selection of an appropriate meter for use by patients at home or for bedside monitoring of patients in hospitals must involve its evaluation for the technical performance.

In this paper, three glucometers(Accutrend Alpha, glucometer Elite and One Touch Basic) were evaluated for their technical performance, these being the ones commonly marketed in Nigeria. The technical performance of these glucometers were evaluated by comparison with laboratory methods. Linearity, accuracy, effect of haemolysis, effect of haematocrit and precision studies at physiological and pathological blood glucose levels were assessed.

Materials and methods

Laboratory assessment of three types of glucometers was carried out; these were Accutrend Alpha, Glucometer Elite and One Touch Basic. The features are summarized in table 1. All meters, test strips and quality control materials were supplied by representatives of their manufacturers in Nigeria. Additional quality control materials were used (Beckman decision controls). Capillary and venous blood samples were obtained from diabetic patients at the phlebotomy room of the Lagos University Teaching Hospital and also from apparently healthy individuals.

The blood specimens were made up of both fasting and random samples. Capillary blood was obtained by use of spring load lancets for finger-pricks to obtain sufficient blood

from subjects. This capillary whole blood was placed on the reagent strips of corresponding meters and were automatically analyzed. Venous blood was collected using a five ml syringe and needle from the antecubital fossa of patients into heparinized bottles. Analyses on the glucometers were carried out simultaneously with that in the main laboratory within 30mins of collection.

In the laboratory, determination of plasma glucose was done by the glucose oxidase oxygen depletion rate method on Beckman CX3 equipment; Day to day precision of this method was 2-4% during this study. The manufacturers provided only one normal control sample per meter and this was analyzed in addition to low and high Beckman control sera for the precision studies. Intra-assay precision using high glucose capillary blood specimens from diabetic patients was then evaluated; each was run 10 times. Inter-assay precision was carried on 20 consecutive days using pooled plasma from patients at a concentration of 180-250mg/dl. The plasma was stored in aliquots at -20°C and one aliquot was analyzed per day.

Linearity was evaluated by using multiple venous spiked samples. These samples were collected and left for 48 hours to allow glucose concentration to approach zero (glucose measurements in all three glucometers read low and did not give any readings), An aliquot was spiked to a concentration of 800mg/dl and then diluted down with unspiked blood. All samples were analyzed simultaneously by the glucometers and by the reference method within 30minutes of dilution.

The meter accuracy was determined by comparison of glucose values obtained using the meters with values obtained by the laboratory reference method using patients samples at high, normal and low glucose concentrations; The plasma was immediately separated and analyzed on the Beckman CX3 auto-analyzer within 30minutes of the analysis on the glucometers. A total of 30 (comprising low, normal and high glucose concentrations) samples were used for this aspect of the study.

Mild to moderate haemolysis was obtained by agitation. Measurements were carried out both on the glucometers and in the laboratory before and after agitation. The effect of haematocrit was evaluated by collecting venous blood into heparinized bottles and separating plasma from the cells. Re-combination of the aliquots was done in different proportions to give blood samples with a wide range of haematocrit values. The baseline glucose analysis was carried out. After the re-combinations, glucose measurements were carried out on all the aliquots. The packed cell volume of each aliquot was also done simultaneously. Volume effect was tested by using varying amounts of capillary blood from 5-40µl of patient's samples on the test strip, the exception was the glucometer elite which accepts only 5µl by capillary action.

Results

The data for the technical performance of the meters and the other features are listed in Table 1.

Precision studies

Intra-assay: At low glucose concentration using the commercial control sera, the Elite Glucometer gave no reading while the Accutrend Alpha had the best precision of 4.5% and the One Touch Glucometer gave a precision of 5.0%. At a normal glucose concentration using controls provided by the manufac-

turers, Glucometer Elite gave the best precision of 6.4%, Accutrend Alpha gave 7.4% while One Touch had a CV of 11.0%. At high glucose concentration using the commercial control sera, the Glucometer Elite also gave the best precision of 1.2% while the Accutrend Alpha and One Touch gave CVs of 4.2% and 4.4% respectively. Using patients samples at a glucose concentration of 200-250mg/dl, Glucometer Elite gave the best CV of 1.4%.

Table 1: Features and technical performance of glucometers

Parameter	Accutrend alpha	Glucometer elite	One touch
Precision			
<i>Intra-assay (n=0)</i>			
Control			
37-51mg/dl	4.5%	No reading	5.0%
79-116mg/dl	7.4%	6.4%	11.0%
<i>Intra-assay (n=10)</i>			
Patient			
200-250mg/dl	4.0%	1.4%	4.6%
<i>Intra-assay (n=20)</i>			
180-250mg/dl	1.9%	6.0%	8.8%
Correlation coefficient (P<0.01)	0.990	0.996	0.991
<i>% deviation from laboratory values</i>			
102.8±2.0mg/dl	-10.5%	-3.7%	+0.2%
231±1.6mg/dl	-4.8%	+3.0%	-
2.15%			
385±2.5mg/dl	+1.1%	+3.7%	-4.6%
<i>Linearity (mg/dl)</i>			
Manufacturer's limit	500	600	500
Lab. assessment	420	453	500
Mean reduction In concentration Following haemolysis			
Mild (mg/dl)	8	16	5
Moderate (mg/dl)	27	29	18
Minimum volume of blood (ul)			
	15	5	20
Reaction time (sec)			
	12	30	45
Weight (without battery)			
	50g	50g	105g
Method			
	Reflectance	Electronic sensor	Reflectance

Inter-assay: Accutrend Alpha gave the best precision of 1.9% at a glucose concentration of 180-250mg/dl while Glucometer Elite and One Touch Glucometers had CVs of 6.0% and 8.8% respectively.

Accuracy: The accuracy of the meters was evaluated by comparison with reference laboratory methods. This was done at blood glucose levels of 80-160mg/dl and 220-400mg/dl. The raw data were used for the correlation studies using Pearson correlation and all 3 meters were found to correlate extremely well with the laboratory reference method. The correlation coefficients (r) were in the range of 0.990-0.996.

Linearity: The limit of linearity for the Accutrend Alpha, Elite and One touch Basic glucometers were 420mg/dl, 453mg/dl and 500mg/dl respectively. These ranges are in agreement with those specified by the manufacturers which were 500mg/dl, 600mg/dl and 500mg/dl for the Accutrend, Elite and One Touch respectively.

Interference from haemoglobin: On mild haemolysis, One touch basic was the least affected with a mean reduction of 5mg/dl while Accutrend was reduced by 8mg/dl and Elite by 16mg/dl on same samples. On moderate haemolysis, One touch basic had a reduction in glucose concentration by 18mg/dl, while Elite and Accutrend were reduced by 28mg/dl and 27mg/dl respectively.

Effect of haematocrit: It was found that at normal haematocrit levels there was no significant effect on the blood glucose levels but at a PCV of >50%, the blood glucose concentration started decreasing (Figures I, II). This was observed in all three glucometers at both normal and at pathological glucose concentrations.

Capillary vs venous blood: The capillary blood glucose was slightly higher than the venous blood glucose levels in the non-fasting subjects but in the fasting subjects there was no difference. The whole blood glucose was about 8-10% lower than plasma glucose values in all three glucometers. Comparing capillary blood glucose results done simultaneously on the three glucometers, One Touch Basic Glucometer readings were 6-18mg/dl lower than those obtained in the Elite and Accutrend Alpha Glucometers while the Glucometer Elite readings were about 10mg/dl higher than the Accutrend Alpha readings.

Volume effects: The least volume that would give reliable results for the Accutrend Alpha and One Touch Basic was 20 μ l. The Glucometer Elite takes exactly 5 μ l by capillary action.

Discussion

Methods for point of care glucose measurements have evolved substantially since first introduced about twenty-two years ago. This is so because intensive insulin therapy has become a standard treatment regimen in type one diabetes mellitus and type II diabetes also requires close monitoring of blood glucose levels. A lot of these glucometers are now in widespread use.

Evaluation of the technical performance of glucometers is often based on accuracy goals defined by the American Diabetic Association (ADA). In 1987, the ADA recommended that glucose concentration determined by portable meters should fall within $\pm 15\%$ of laboratory values for meters available at that time; The goal of future meters should be to reduce this variability to within $\pm 10\%$ at concentration between 30-400mg/dl 100% of the time [3].

In 1994 and 1996, further consensus statements stated the limit as $\pm 5\%$ of laboratory results for future glucometers [4]. Previous studies have not been able to achieve these criteria. Gifford Jorgensen *et al* [5] found an accuracy which was between 35-70% in 5 different glucometers; Bain [6] in 1991 observed glucose meter readings exceeding $\pm 15\%$ in three meters (27-43%) while Chance [7] in 1999 reported an improvement with percentages ranging from 2.9-14.7%.

In our present study, the accuracy was between 0.2-10.5% of laboratory results for the three glucometers (Table 1),

it would appear that the One Touch Basic glucometer had the least deviation from the laboratory values. This is yet an improvement over previous studies. There was excellent correlation between the glucometer readings and the laboratory results in all three glucometers. A study by Devreese [8] also reported an excellent correlation between the glucometers studied which included One Touch and Accutrend and the laboratory method (Hexokinase) used which was different from the glucose oxidase method used in this study.

In a recent study [9], glucometers were classified into old and new meters; Accutrend Alpha and One Touch were in the old group while the Glucometer Elite was in the new group. There was an improvement in accuracy in the new set of glucometers over the old meters. This was probably due to the technique (electronic sensor) and the smaller blood volumes used. From our present study, the accuracy is not significantly higher than the other two older glucometers.

The accuracy failure rates in previous studies [6,7] stated were found to increase when the meters were used by diabetics especially in children with insulin dependent diabetes. In this study however there was no such observation since all the analyses were carried out by pathologists. The percentage deviation from reference values has been suggested as a clinically useful measurement of accuracy apart from the correlation.

Within-run (intra-assay) precision studies in this study show that the glucometer Elite Glucometer may not be the best choice in cases of hypoglycaemia while it had the best precision at high glucose levels. Kaylun Li *et al* [10] compared 8 glucometers, the mean intra-assay CV (of all the glucometers) at low concentration was between 2.8-16.1% while at high concentration it was between 1.8-18.4%. Comparing this with our present study we would say there is an improvement over their study, the highest CV in our study being 11.0% (Table 1). In another study by Raimund Weitgasser *et al* [9], the Elite and Accutrend glucometers were part of 8 glucometers assessed, the mean intra-assay CV for the Elite and Accutrend glucometers were 3.8% and 2.5% respectively at a glucose concentration of 162-180mg/dl while at a concentration of 270-283mg/dl the CV was 2.1% and 1.5% respectively. In our study, the CV was highest at normal glucose concentration (6.4%-11.0%); the reason is not clear. The linear range indicated for each glucometer was verified. Two of the meters became non-linear (Elite and Accutrend Alpha) at glucose concentrations lower than the upper end specified. In both cases the NCCLS (National Committee for Clinical Laboratory Standards) recommended 20% of reference method was not exceeded.

The whole blood glucose values which were lower than the plasma values in all three glucometers is probably due to interference from red blood cells. It was also noted that in random samples, there was a slight increase in capillary blood glucose level; This is probably due to the fact that in the post-prandial state, the muscles remove more glucose from the blood than the liver does in the presence of adequate insulin action during alimentary hyperglycemia. However this difference is extremely small in the absence of insulin [11].

The effect of haematocrit on blood glucose was similar in all three meters (figure I, II). For normal haematocrit values of <50, the effect is negligible but at higher haematocrit values, there is a decrease in blood glucose. The increase in red blood cells and leukocytes probably increases the rate of glycolysis therefore giving lower glucose readings. This decrease may cause some degree of underestimation of glucose concen-

trations in the few patients that would have a PCV >50%. This finding agrees with previous studies [11,12].

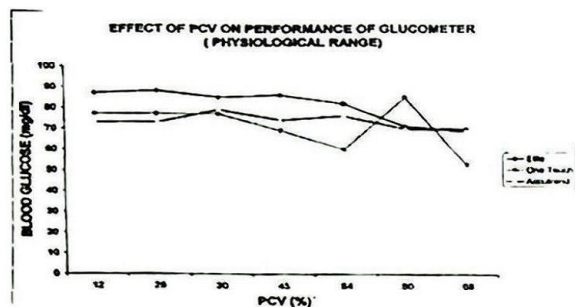


Fig. 1:

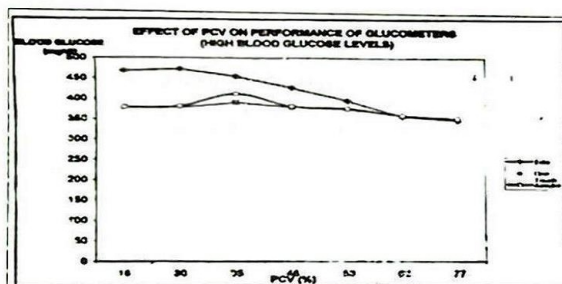


Fig. 2:

The Elite meter is the most portable of the three and it also uses the least amount of blood compared to the Accutrend Alpha and the One Touch meters (Table I), it can also be said to be the most precise at high glucose concentrations and also has very good correlation with the laboratory values. These small portable quantitative meters may in future replace the routine urinalysis done at the antenatal clinic since it is more specific and an earlier indicator of abnormal glucose metabolism than the dipstick method currently used.

In summary, we observed that these meters provide results comparable to laboratory values using patients' samples; based on the precision and accuracy studies, the technical performance of these glucometers can be said to be acceptable. However it is necessary to carry out periodic calibration of these meters with the laboratory reference methods in order to achieve optimum reliability. Patients with haematocrit >50% should preferably have their blood glucose measurements done by the central or main laboratory.

Until reliable non-invasive blood glucose measurement techniques are available for everyday use, further improve-

ment of currently available glucose meters is desirable and necessary. It is also desired that all diabetic patients and all emergency/intensive care units have portable glucose meters, as this would definitely improve patient care.

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1. ISN Nigeria limited, Gbagada, Lagos. Suppliers of Accutrend Alpha.
2. Unichem Nigeria limited, Oregun, Lagos. Suppliers of Glucometer Elite.
3. Salenab Nigeria Limited, Ikeja, Lagos. Suppliers of One Touch Basic.

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