Evaluation of capillary glucose meter: CaresensN™

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Background

Capillary blood glucose meters must have sufficient accuracy to allow patients and clinicians to monitor glycaemic control and then make safe modifications to treatment, based on these results. Establishing the accuracy and reliability of these meters involves determining the technical sources of error and defining operator and patient related factors, such as extremes in haematocrit, that may affect the blood glucose measurements. Technical accuracy is assessed by examining the agreement between a capillary glucose result measured using a meter and a reference method such as a laboratory plasma glucose assay. The criteria used to assess the acceptability of glucose meters are the National Committee on Clinical Laboratory ISO15197 standards[1] which stipulate that <5% of readings should fall outside the limits of ±20% from the reference value or ±0.83 mmol/L if the glucose level is <4.0 mmol/L. These limits have been used to construct error grids such as the Clarke[2] or Consensus[3] grids. The benefit of these grids is that they show the clinical acceptability of the blood glucose values measured, relative to the reference plasma glucose assay. Other methods used to compare glucose results from meter and laboratory plasma tests include Passing and Bablok regression analysis and Bland-Altman plots[4] which help determine whether there is evidence of systematic bias.

The present series of studies represents an extension of our earlier investigations on several blood glucose meters available in New Zealand[5-6]. The methodology used in the current study is similar to that described in these earlier investigations and is based on previously published methodology[5]. One of the pre- analytical issues that can have a strong influence on laboratory glucose results is the amount of time venous glucose is left in the test tube before centrifugation. In this study glucose was centrifuged within 10 minutes of collection. The meter assessed in this study was the CareSensN™ .

Description of meter studied

CareSens N™ Blood Glucose monitoring system

Manufacturer	i-SENS Inc
Features	Two test strip points Plasma equivalent calibration. Storage of previous 250 test results
Assay method	Electrochemical
Sample size	0.5 microlitre
Test time	5 seconds
Result range	1.1 to 33.3 mmol/L

Methodology

The accuracy and precision of the blood glucose meter was assessed according to the methodology described by Florkowski et al[5]. The study was carried out at the Diabetes Centre, Christchurch Hospital. Briefly, capillary blood samples and venous plasma samples were collected simultaneously from patients attending the outpatient clinic. Patients were excluded if their haematocrit level was <0.30.

The samples were collected by Diabetes Research Nurses using a spring-loaded sterile lancet. Capillary glucose concentration was measured in duplicate immediately after blood collection using two different CareSensN meters. The venous blood samples were collected into lithium heparin-anticoagulated vacutainers, centrifuged within 10 minutes, and the plasma glucose concentration measured by the hexokinase method using an Abbot ci8200 automated analyzer. These assays were carried out by Canterbury Health Laboratories.

For each patient, the mean value of the readings from the meter was calculated. Differences between the capillary and venous glucose concentrations were analysed using the following methods.

1. Error grid analysis using the Clarke and also the modified version, known as the Consensus method (EP Evaluator®9, Data Innovations)
   Compares capillary and plasma glucose concentration to determine the potential clinical significance of any difference.

2. Bland-Altman analysis (Sigmastat for Windows ver10)
   Analyzes the agreement between two assays by plotting differences between methods against the average concentration.

3. Spearman Rank correlation analysis of difference
   Determines systemic bias and the effect of haematocrit.

4. Passing-Bablok regression analysis
   Determines whether there is a significant deviation from linearity in the differences between the glucose meter measurements and the reference plasma glucose assay.

The precision of the CareSensN™ meters was also determined by replicate analysis (n= 20) of high- and low- glucose quality control solutions. Two different batches of test strips were tested for each meter. The percentage variation of the two meters was then calculated.

This study had regional Ethics approval

Results

Characteristics of the 56 adult participants (40 males, 16 females) was as follows; mean age 56.5 (SD± 15.5) yr; type 1 diabetes n=14, type 2 diabetes n=41, maturity-onset diabetes of the young [MODY] n=1). No patient had a haematocrit <0.30. Detailed statistical interpretation of the glucose results shown in the Figures is given in the Tables which follow on from the Figures. The assessment of the effect of haematocrit on glucose recordings is also shown in Table 4. In summary, haemaocrit had no effect on glucose measurement.

CaresensN™ Error grid analyses

Figure 11a

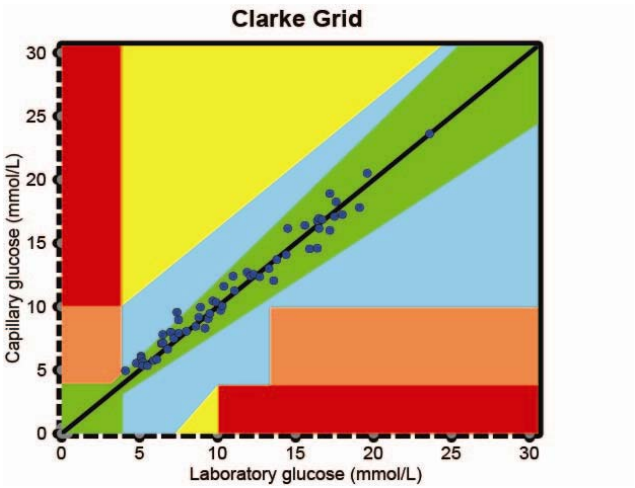
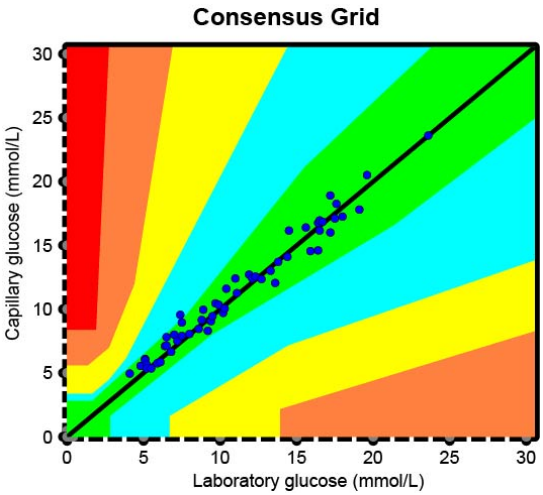


Figure 11b



Zone A: No effect on clinical action

Zone B: Altered clinical action, but little or no effect on clinical outcome

Zone C: Altered action, likely to affect the outcome

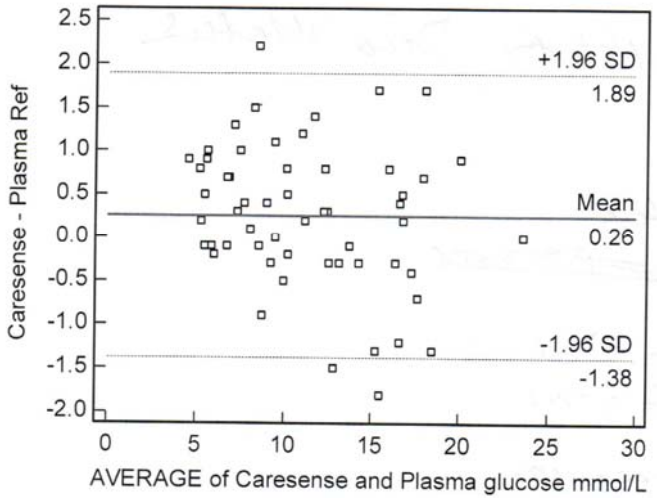
Zone D: Significant medical risk

Zone E: Could have dangerous consequences

Zone	Clarke Grid	Consensus Grid
A	54/56 (96.4%)	55/56 (98.2%)
B	2/56 (3.6%)	1/56 (1.8%)
C	0/56	0/56
D	0/56	0/56
E	0/56	0/56

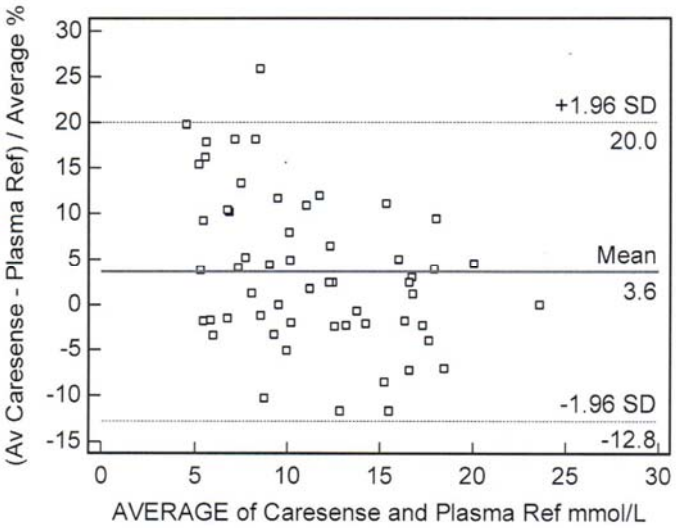
CaresensN™ Bland-Altman plots

Figure 12 Difference between methods



Mean = 0.26

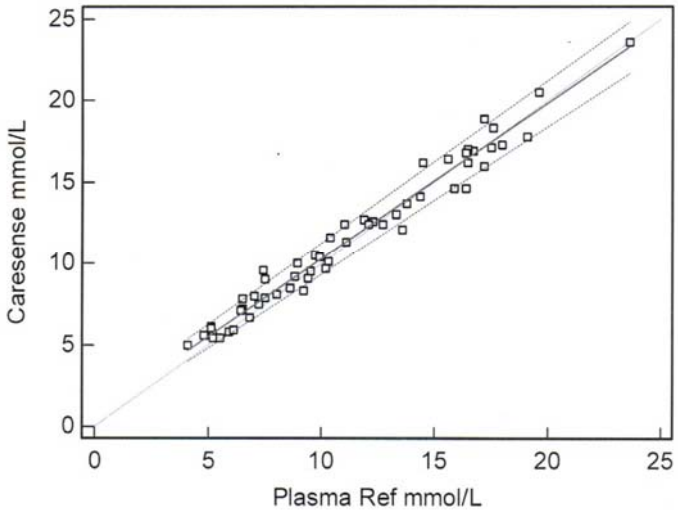
Figure 13 % Difference between methods



Mean = 3.62%

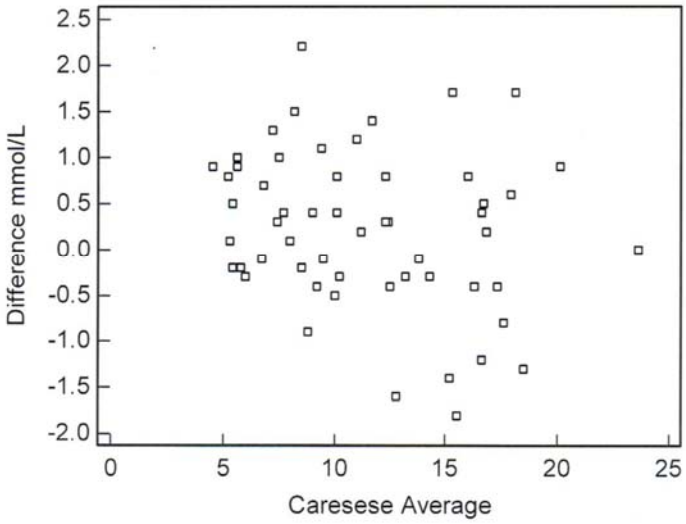
CaresensN™

Figure 14 Passing and Bablok regression



y = 0.75+0.96x
Intercept A = 0.75 (95% CI 0.30-1.25)
Slope B = 0.96 (95% CI 0.91-1.00)

Figure 15 Spearman Rank correlation analysis of difference



No systematic bias

Summary tables

Table 1 Error grid analysis

	Figure	Percentage in Zone A		Percentage in Zone B	
		Clarke	Consensus	Clarke	Consensus
CaresensN	11a, 11b	96.4	98.2	3.6	1.8

Table 2 Bland-Altman plots

	Difference (mmol/L)		% Difference (mmol/L)	
	Mean (SD)	95% CI	Mean (SD)	95% CI
CaresensN	0.26 (0.83)	0.03 – 0.48	3.62 (8.40)	1.38 – 5.86

Table 3 Passing and Bablok regression

	Slope of regression line	95% CI	Deviation from linearity (Cusum)
CaresensN	0.96	0.91 – 1.00	**No significant deviation from linearity**

Table 4 Spearman rank correlation analysis of difference

	Systemic bias Spearman Coefficient (rho)	p	Haematocrit Spearman Coefficient (r)	p	Result
CaresensN	-0.25	0.07	-0.21	0.13	**No systematic bias** **No effect of haematocrit**

Table 5 Percentage variation (CV %) in replicate testing (n=20)

	% variation at low glucose level		% variation at high glucose level	
	Strip 1	**Strip 2**	**Strip 1**	**Strip 2**
CaresensN	3.5%	5.8%	2.3%	4.0%

Summary of results

- The meter performed satisfactorily and complied with the criteria set by the National Committee on Clinical Laboratory and ISO15197 standards.

- Error grid analysis showed that <5.0% of the individual plots were outside zone A.

- Passing and Bablok regression (Table 3) showed no significant deviation from linearity in the difference between the reference plasma glucose assay and capillary blood glucose measured by the meter.

Additional comments

Meter performance appeared similar or even better than that seen in our earlier assessment of glucose meters in 2009,[5] however sample size is small and there may have been minor technical improvements in the current study's methodology, such as very rapid centrifugation, that make direct comparison of the 2009 study with the current study somewhat difficult. Although we have reported that all meters perform to ISO standards,[1] more stringent performance goals have been suggested.[7] The analyses also showed haematocrit level in the normal range had no significant effect on glucose estimation with any of the meters studied.

Additional Study Limitations

The accuracy and reliability of the meter for self-testing of patients with diabetes should be assessed under field conditions. Long term strip stability and the possibility of damaged strips producing artefactual results (rather than an error message), was not assessed. Ease of meter download and use of associated data display software was also not assessed.

Conclusions

The CareSensN meter performed satisfactorily and complied with International guidelines for measurement of capillary glucose levels.

The meter tested had comparable, if not slightly improved performance, to meters assessed previously. This improvement involved more accurate measurement at higher glucose levels, as shown by the reduced level of correlation in regression analyses in the current study.

We conclude that under controlled conditions and using trained operators the CareSensN meter is acceptable for operational use for point of care testing.

References

1. **International Standard ISO 15197. In vitro diagnostic test systems – Requirements for blood-glucose monitoring systems for self testing in managing diabetes mellitus. ISO 15197:2003 (E). ISO copyright office, CH-1211, Geneva 20, Switzerland.**
2. **Clarke WL, Cox D, Gonder-Frederick LA, Carter W, Pohl SL. Evaluating clinical accuracy of systems for self-monitoring of blood glucose. Diabetes Care 1987;10:622-8.**
3. **Parkes JL, Slatin SL, Pardo S, Ginsberg BH. A new consensus error grid to evaluate the clinical significance of inaccuracies in the measurement of blood glucose. Diabetes Care 2000;23:1143-8.**
4. **Bland JM, Altman DG. Comparing methods of measurement: why plotting difference against a standard method is misleading. Lancet 1995;346:1085-7.**
5. **Florkowski C, Budgen C, Kendall D, Lunt H, Moore MP. Comparison of blood glucose meters in a New Zealand diabetes centre. Ann Clin Biochem 2009;46:302-305.**
6. **Lunt H, Kendall D, Florkowski C. Evaluation of four capillary glucose meters. Pharmac report 2009.**
7. **Sacks *et al*. Position Statement Executive summary: Guidelines and recommendations for laboratory analysis in the diagnosis and management of diabetes mellitus. Diabetes Care 2011;34:1419-23.**