Original Article

DOI: 10.7860/JCDR/2015/13357.6664

Biochemistry Section

Evaluation of CareSens POCT Devices for Glucose Testing in the Routine Hospital Setting

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ABSTRACT

Introduction: Glucose meters are used routinely in hospital wards to manage blood glucose levels in patients requiring frequent monitoring of blood glucose.

Objective: Our institution has 50 POC instruments utilized by diverse population of all ages and medical conditions. The primary objective of our study was to investigate whether all these CareSens glucose meters (I-sense Inc, Seoul, South Korea) results in hospitalized patients during routine clinical care jointly satisfy the specified quality specifications, as defined by Clinical and Laboratory Standards Institute (CLSI) guideline POCT12-A3.

Materials and Methods: The records of hospitalized patients who underwent simultaneous measures of glucose levels with both glucose meters and a central laboratory analyser between January and June 2013 were retrospectively analysed. We also performed a prospective evaluation of the accuracy of the CareSens glucose Strip.

Results: Glucose concentrations measured in 840 patients ranged from 1.66 to 31.72 mmol/L The Bland–Altman difference plot between the auto analyser and all the 50 CareSens glucosemeters revealed a mean bias of -2.2%, with analytical biases for the two methods varying from –31.1% to 26.8%. Eighty four percent of the glucose meter's glucose values were within ± 12.5% for values 5.54 mmol/L of the comparative laboratory glucose values and 93% of the results were within 20% of the reference for glucose >4.2 mmol/L and 65% of the results were within 0.8 mmol/L for glucose <4.2 mmol/L.

Conclusion: CareSens glucose meter readings in hospital settings, especially in hypoglycaemic patients, should be confirmed by central laboratory analysers whenever possible.

Keywords: Autoanalysis, Blood glucose, Methods, Qualitycontrol

INTRODUCTION

Glucose meters are used routinely in hospital wards to manage blood glucose levels in patients requiring frequent monitoring of blood glucose. Glucose meters offer advantages, including rapid turnaround times and use of minimal blood volumes [1,2]. Proper monitoring and treatment of patients, however, require that the analytical performance of glucose meters be acceptable when compared with laboratory analysers [3,4].

Because most of these devices originally designed and manufactured for home use, significant variation among these monitoring devices exist, leading to the development of multiple guidelines for glucose meter accuracy. The American Diabetes Association (ADA) has recommended that the difference between glucose meters and the laboratory method should be less than ±15%, the recommendation was modified, for the maximum analytical error to be <5% [5]. International Standards Organization (ISO 15197:2013) requires that 95% of results from a glucose meter be within 15% of results obtained from a reference measurement such as a central laboratory hexokinase method [6]. POCT12-A3 glucose meter guideline from the Clinical Laboratory Standards Institute that covers glucose meters used in hospitals stipulates that 95% of the results must have differences from the laboratory analyser less than 0.66 mmol/L below 5.54 mmol/L and less than 12.5% above 5.54 mmol/L and 98% of the results must be within 20% of the reference for glucose >4.2 mmol/L and 0.8 mmol/L for glucose <4.2 mmol/L [7]. A current systematic review revealed that conflicting results have been reported with regard to the accuracy of these devices [8].

Previously, the accuracy of the CareSens glucose meter has been compared with Yellow Springs Instrument glucose oxidase analyser and by the hexokinase method using an Abbott ci8200 automated analyser [9,10]. Both of studies were carried out under controlled conditions by a research team experienced in glucose meter validation which limits the generalisability of the findings to the routine hospital settings.

AIM

Our institution has 50 POC instruments utilized by diverse population of all ages and medical conditions. Our aim was to investigate whether all the 50 CareSens glucose meters (I-sense Inc, Seoul, South Korea) results in hospitalized patients during routine clinical care jointly satisfy the specified quality specifications, as defined by Clinical and Laboratory Standards Institute guideline POCT12-A3.

MATERIALS AND METHODS

Study Design

After obtaining Sevket Yilmaz Research and Education Hospital Ethics Committee approval with waiver of informed consent, we performed a retrospective review of all internal quality control data performed in Sevket Yilmaz Research and Education Hospital from January 1, 2013, to June 30, 2013.

All capillary blood samples were taken at room temperature after verification and calibration of the devices and additional blood sample was drawn, at the same time, using a vacuum technique featuring clot-activating tubes (Green-Vac, Yongin, Korea); the samples were immediately sent, pneumatically sealed, to our central laboratory. Nurses were trained to take venous samples within 5 minutes they measured capillary blood glucose. Chief technician controlled the blood collection time in those different warts as part of our internal quality control procedure. Blood sampling time was between 8am-3 pm in all these clinics. None of the blood samples obtained from arterial catheters, central and peripheral venous catheters and capillary (needle sticks) samples. This approach was carried out every 15 days and all results, for all patients, based on their glucose meter and the corresponding laboratory measurements, were recorded by the laboratory director.

Although this study was not performed in strict compliance with the methodology outlined in Clinical and Laboratory Standards Institute guideline POCT12-A3, the methods for system accuracy data analysis and assessment have been followed.

Capillary samples

CareSens test strips require 5 µL blood and test results are derived by converting an electrochemically generated signal to a glucose concentration by means of an algorithm based on the glucose oxidase method. According to the manufacturer's instructions, all of the meters in use have a linearity range of 1.10-33.27 mmol/L glucose. The laboratory provides direct oversight of glucose meters and their use and operator validation is a continual process. The glucose meters were calibrated each day according to manufacturer specifications.

We regularly check the quality of glucose meters and test strips as a part of our IQA programme. The devices calibrated and verified using the commercial control materials daily. In all of the 50 point of care (POC) testing sites, two internal quality control materials (Control solutions, I-sense Inc, Seoul, South Korea) were analysed in every 15 days. The precision of each meters was also determined by replicate analysis (n=20) of the normal, high and low glucose quality control solutions in the same day.

Comparison of Glucose Meters with the Central Laboratory Analyser.

Venous blood samples for testing by the central analyser were obtained from the same 840 patients within 5 minutes of measuring glucose concentrations in capillary blood samples with the glucose meters. Serum were separated by centrifugation at 3500 rpm for 10 min and analysed within 30 minutes from blood collection, as part of our standard operating procedures. We also compared results of 60 different patients in one glucose meter with auto analyser in one day. Serum glucose concentrations were analysed by a hexokinase method on Architect C16000 (Abbott Laboratories, Abbott Park, IL, USA), which was linear in the range of 0.06-44.40 mmol/L glucose. The imprecision of the Glucose assay is 1.92% as declared by the manufacturer. Hexokinase methods are suitable for use as reference methods for glucose determination because they correlate closely to definitive mass spectrometry [6]. For quality assurance purposes, our laboratory participates in the Klinik Biyokimya Uzmanları Dernei external quality control programme (Association of Clinical Chemists, Turkey) external quality assessment scheme ran during the study interval.

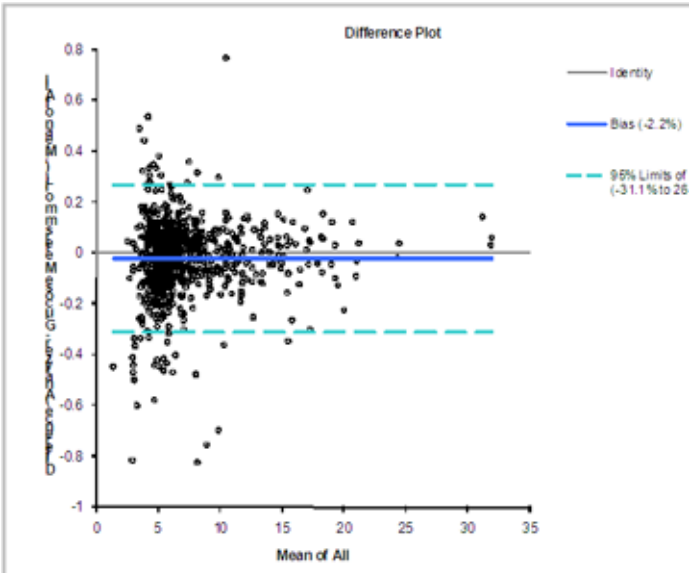
STATISTICAL ANALYSIS

Means, standard deviations, and coefficients of variation were calculated by Analyse-It version 2.04 (Analyse-It Software, Leeds, UK). Bland-Altman plots were evaluated by Analyse-It version 2.04 (Analyse-It Software, Leeds, UK) [11]. The Bland–Altman method plots the mean of paired glucose values versus the absolute difference between the paired values [11] which show bias and variation from reference of glucose meter measurement over a range of glucose concentrations.

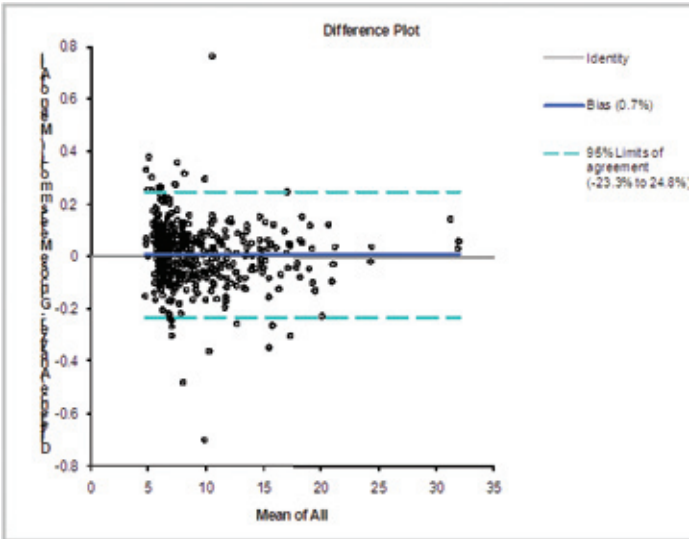
RESULTS

Day to day precision of device using the CareSens quality control materials (I-sense Inc, Seoul, South Korea) yielded average coefficients of variation of 5.9% for the low control (mean 3.38 mmol/L) and 4.3% for the high control (mean 18.38 mmol/L). Average coefficients of variation of the control materials within run precision with one strip lot were of 3.4% for the normal control (mean 7.40 mmol/L), 6.1 for the low control (mean 3.71 mmol/L), and 4.1% for the high control (mean 16.98 mmol/L) respectively.

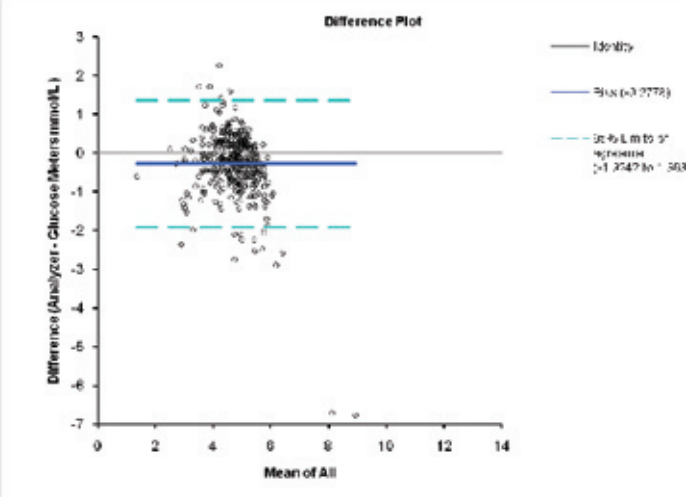
The Bland–Altman difference plot between the auto analyser and 50 glucosemeters jointly revealed a mean bias of -2.2%, and the 95% limits of agreement (average difference ± 1.96 standard deviation of the difference) of –31.1% to 26.8% for the glucose meter and autoanalyser difference [Table/Fig-1]. When we grouped the patients according to their glucose levels, the mean bias was -0.7% above 5.54 mmol/L range and 95% limits of agreement



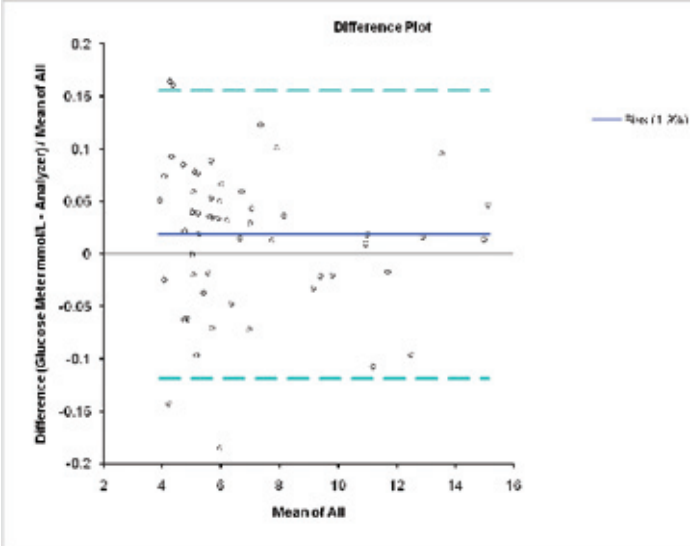
[Table/Fig-1]: Bland–Altman plot of the correlation between glucose meters and central laboratory analyser measurements of glucose concentrations in all patients (n=840)



[Table/Fig-2]: Bland–Altman plot of the correlation between glucose meters and central laboratory analyser measurements of glucose concentrations above 5.54 mmol/L range (n=450)



[Table/Fig-3]: Bland–Altman plot of the correlation between glucose meters and central laboratory analyser measurements of glucose concentrations below 5.54 mmol/L range (n=390)



[Table/Fig-4]: Bland–Altman plot of the correlation between one glucose meter and central laboratory analyser measurements of glucose concentrations in sixty patients

-24.8% to 23.3% [Table/Fig-2]. Eighty four percent of the glucose meter's glucose values were within ± 12.5% for values 5.54 mmol/L of the comparative laboratory glucose values. The mean bias was -0.27mmol/L below 5.54 mmol/L range and 95% limits of agreement 1.36 to 1.93 [Table/Fig-3]. Seventy five percent of the results have differences from the laboratory analyser less than 0.66 mmol/L below 5.54 mmol/L glucose concentrations. Ninety three percent of the results were within 20% of the reference for glucose >4.2 mmol/L and 65% of the results were within 0.8 mmol/L for glucose <4.2 mmol/L (n=77).

The Bland–Altman difference plot between the results of 60 patients with auto analyser and one glucose meter revealed a mean bias of 1.9%, and the 95% limits of agreement of –11.4% to 15.1% for the glucose meter and autoanalyser difference [Table/Fig-4].

DISCUSSION

We found significant differences between the readings obtained using the CareSens glucose meters and those from the central laboratory analyser. Ninety four percent of the new meter's glucose values were within ± 12.5% for values ≥ 5.54 mmol/L of the comparative laboratory glucose values, and 93% were within ± 20% ≥ 4.2 mmol/L. The number of glucose values outside CLSI guideline limits was high and evenly split above and below the CLSI limits. Given that the glucose meters were operated by well-trained nurses, it is unlikely that these differences were due to operator error. The glucose meter readings may, however, have been affected by the various drugs, hormones, and additives detected in hospitalized patients [12]. Use of a large number of samples from 50 different units should include the vast majority of drugs and potential interfering substances that might be encountered in these patients.

Our study provides information on glucose meter performance in the hospital setting in which numerous glucosemeters are used. Methods such as ours can ensure the quality of glucose meter performance is appropriate in routine clinical settings. Bias of the glucose meter compared with the reference measurement method has been reported in several studies [13,14]. In the absence of a capillary reference standard, it is difficult to determine whether these discrepancies were due to glucose meter inaccuracy or the physiological differences between venous and capillary blood samples. Although these samples might vary slightly, at least 95% of capillary results should show an analytical variance of <20%, when compared with laboratory results [13-16].

Use of glucose meters to test hospitalized patients for hypoglycaemia or severe hyperglycaemia reinforces the need for tight control. Within day and day to day imprecision of CareSens glucose meters using quality control materials demonstrated % CV of > 5% at glucose levels <5.6 mmol/L which indicates that these glucose meters has low degree of repeatability and reproducibility in the hypoglycaemic blood glucose levels [7].

The Bland–Altman difference plot between the auto analyser and CareSens glucose meters revealed a mean bias of 1.9% that seems to ensure good concordance with the laboratory method and similar to found by Kong and colleagues [17]. Several studies have shown that Care Sens glucosemeters read higher than the reference device [10,18]. Cohen et al., compared results of four different glucose meters with the reference method YSI Glucose Analyser (Yellow Springs Instruments, Ohio, USA), with only the CareSens meter <5% bias [9]. Parks et al., compared glucose concentration using CareSens, with an automated chemical analyser (747; Hitachi, Tokyo, Japan) using hexokinase (Climate GLU; DAIICHI, Tokyo, Japan) method. Glucose meter was measured consistently lower than auto analyser by approximately 5% [18].

The results obtained from the Bland-Altman plot show that the deviation of CareSens glucose meter in the low blood glucose ranges mainly results from overestimation of blood glucose values, in relation to the central analyser as the reference method. This may, therefore, result in an underreporting of hypoglycaemia, which might have clinical consequences.

Because many studies have shown that even mild hypoglycaemia is significantly associated with increase in mortality [19,20], accuracy of blood-glucose monitoring in the hypoglycaemic range is important. We observed ≥0.8 mmol/L differences between glucose meter and autoanalyser concentrations in 35% of hypoglycaemic samples, and these differences are not acceptable in hospitalized patients. We should be aware that a greater possibility of errors exists in the hypoglycaemic range than in the non-hypoglycaemic range.

Depending on the ICU population, approximately 5–20% of critically ill patients have diabetes [8]. Patients with falsely elevated glucose concentrations may be treated with an insulin overdose, while those with falsely underestimated concentrations are at increased risk of developing hyperosmolar coma.

LIMITATIONS

The retrospective nature of our study precluded analysis of potential reasons for poor accuracy in our patient population. Sodium and haematocrit levels were not recorded for the patients and with the current study design, we are unable to determine whether the difference in glucometer reading is due to drug that they are taking. Although well-trained nurses instructed to perform the procedure we are not sure that blood samples were collected within 5 minutes from the capillary blood sampling. Also, we didn't investigate technical and analytical performance of the nurses and its possible for them to misunderstand manufactures guideline of glucometer.

CONCLUSION

Erroneous results are not infrequent when glucose concentrations are measured with POCT glucose meters. Caution is required in interpreting POCT glucose meter results measured, as there were large, unpredictable errors in both directions from the reference BG value. Patients found to be hypoglycaemic or hyperglycaemic should be retested with a laboratory analyser to minimize misdiagnoses. This study demonstrated that careSens is not sufficiently accurate by health care professionals in all nursing units including the intensive care unit.

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FINANCIAL OR OTHER COMPETING INTERESTS: None.

Date of Submission: **Feb 26, 2015**
Date of Peer Review: **Jun 29, 2015**
Date of Acceptance: **Aug 31, 2015**
Date of Publishing: **Oct 01, 2015**