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Accuracy of the CONTOUR® Blood Glucose Monitoring System

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Abstract

Objective:

The aim of the study was to assess the accuracy of the CONTOUR® blood glucose monitoring system (BGMS) according to the International Organization for Standardization's International Standard 15197 (ISO 15197:2003) guidelines and to more stringent criteria.

Method:

Finger stick blood samples from 105 subjects with diabetes (25 with type 1, 77 with type 2, and 3 with type unknown) were tested using the CONTOUR BGMS and YSI glucose analyzer.

Results:

99.3% of results were within ISO 15197:2003 criteria (±15 mg/dl of YSI results at glucose concentrations <75 mg/dl and ±20% at glucose concentrations ≥75 mg/dl). Additionally, 96.7% of results were accurate according to more stringent criteria (±15 mg/dl of YSI results for glucose concentrations <100 mg/dl and ±15% for glucose concentrations ≥100 mg/dl). Error grid analysis showed that 99.3% and 0.7% of results were within zones A and B, respectively.

Conclusion:

The CONTOUR BGMS exceeded both the minimum acceptable accuracy based on ISO 15197:2003 and the more stringent accuracy criteria.

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Introduction

The International Organization for Standardization's International Standard 15197, Section 7 (ISO 15197:2003) describes an accuracy evaluation for blood glucose monitoring systems (BGMS).[1] The accuracy evaluation described in Section 7 of the standard is a design verification activity to assess the analytical accuracy of the system under controlled conditions in the hands of trained operators. The CONTOUR® family of products from Bayer HealthCare includes the BGMSs CONTOUR, CONTOUR LINK, CONTOUR USB, and DIDGET® that

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Abbreviations: (CDC) Centers for Disease Control and Prevention, (CI) confidence interval, (FDA) U.S. Food and Drug Administration, (ISO) International Organization for Standardization

Keywords: blood glucose monitoring, CONTOUR, diabetes, self-monitoring of blood glucose

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all utilize CONTOUR test strips and CONTOUR TS that utilizes CONTOUR TS test strips. Frank and colleagues[2] reported the performance of CONTOUR TS in the hands of lay users and health care professionals. CONTOUR and CONTOUR TS systems are designed to meet the individual needs of various people with diabetes and therefore have different sets of features. For example, the CONTOUR system includes customizable features such as pre- and post-meal markers and a selectable post-meal reminder. CONTOUR and CONTOUR TS BGMSs are over-the-counter devices indicated for the measurement of glucose in whole blood by people with diabetes and by health care professionals.

In this study, the accuracy of the CONTOUR BGMS was assessed in the hands of trained operators according to the analytical performance evaluation outlined in Section 7 of ISO 15197. The goal of this evaluation was to test the performance of the system in the hands of trained operators under optimal operating conditions. Results were expressed using both current ISO 15197:2003 criteria and more stringent criteria.

Methods

The CONTOUR Blood Glucose Monitoring System

Key features of the CONTOUR BGMS that was evaluated in this study are listed in **Table 1**. Visual and functional inspections as well as functional testing were conducted on all meters to verify proper functioning prior to the start of the study.

Reference Glucose Measurement

The YSI 2300 Stat Plus Glucose and Lactate Analyzer (YSI Inc., Life Sciences, Yellow Springs, OH) was used as the laboratory reference instrument in the study. The accuracy of the YSI analyzer was validated with a set of serum-based controls that have been assayed by the Bayer analytical laboratory using the reference hexokinase glucose assay developed at the Centers for Disease Control and Prevention (CDC) and recognized by the U.S. Food and Drug Administration (FDA) and the National Reference Systems for Clinical Laboratories. The standard calibration curve for the CDC method was established with glucose solutions made with NIST SRM 917a (dry D-glucose). NIST SRM 965, which is a set of 3 frozen human serum samples with glucose concentrations of approximately 100, 200, and 300 mg/dl, was used as the control in the CDC method. The target values for the SRM 965 controls were established using the NIST definitive glucose method.

Table 1.
Summary of CONTOUR® Blood Glucose Monitoring System Technology and Features

Specification	Description
Biosensor (test-strip chemistry)	Glucose dehydrogenase flavin adenine dinucleotide
No Coding™ technology	Immediately ready for testing, eliminates errors due to miscoding
Test time	5 seconds
Sample size	0.6 μl
Sampling method	Sip-in-sampling: test strip automatically draws blood (or control solution) into the test chamber
Alternate site testing	Forearm and palm
Quality checks	Meter automatically performs a series of quality checks at the beginning of each test to detect conditions that would affect accuracy (e.g., underfill, temperature, used test strip)
Hematocrit	Automatically corrects for different hematocrit levels within 0% to 70% range
Interfering substances	No maltose or galactose interference;[a] automatically compensates for reducing substances (e.g., acetaminophen, uric acid, ascorbic acid)
Control solution detection	Distinguishes control solution from blood and automatically marks control readings so they are not included in the 14-day average
Memory (number of tests)	Stores up to 480 test results
Test result averages	Level 1: Provides the average blood glucose level based on the total number of tests conducted over the past 14 days Level 2: Provides the average blood glucose level based on the total number of tests conducted over the past 7, 14, or 30 days; also provides 30-day pre- and post-meal test result averages
HI/LO test results summary	Displays the number of high test results (>180 mg/dl), low test results (<72 mg/dl), and the total number of tests over the past 7 days Note: Advanced mode (L-2) allows the user to personalize their HI and LO test settings; the range of values for HI settings is 100–250 mg/dl; the range of values for LO settings is 60–90 mg/dl
Unique test result marking	Log book icon refers user to log book for further information on certain results
Meal markers and post-meal test reminder	Users can mark preprandial/postprandial blood glucose readings and set a test reminder that beeps 1.0, 1.5, 2.0, or 2.5 hours after the preprandial reading

[a] Xylose in the blood will cause interference. The CONTOUR BGMS should not be used during or soon after a xylose absorption test.

Accuracy Evaluation

Accuracy of the CONTOUR BGMS for fingertip capillary blood testing was assessed at a study site in Mishawaka, Indiana (Bayer HealthCare LLC, Diabetes Care). A total of 105 subjects with diabetes were included in the study (age range, 19–82 years). Twenty-five subjects had type 1 diabetes and 77 had type 2 diabetes (diabetes type was not reported for 3 subjects). An institutional review board approved the study, and all subjects gave their informed consent prior to participation. At the study site, a trained operator tested the subject's fingertip blood with the CONTOUR BGMS and a laboratory reference method (YSI glucose analyzer). Each finger stick sample was tested with three different lots of test strips, with duplicate readings per lot for a total of six readings per sample. Immediately after applying blood to the CONTOUR BGMS, approximately 200 µl of additional blood was collected from the finger into a heparinized microcollection tube for testing in duplicate on the YSI analyzer. ISO 15197:2003 specifies that the glucose concentrations of the finger stick samples shall be distributed as specified in **Table 2**. As noted in the standard, a sufficient number of fresh capillary blood samples with very low and very high glucose concentrations may be difficult to obtain from patients.[1] To ensure a sufficient number of samples within the specified concentrations, modified blood samples were prepared per the ISO 15197:2003 protocol. Heparinized venous blood was allowed to glycolyze to produce low glucose levels or was supplemented with 20% glucose stock solution to produce high glucose levels (n = 26). Therefore, the total number of blood samples included in the study was 100 (or 74 samples from 105 patients plus the 26 contrived samples). The total number of meter readings was 600 (that is, each sample was tested with 3 test strip lots and 2 tests were conducted per lot for a total of 600 readings). Accuracy was evaluated using ISO 15197:2003 criteria and by calculating the percentage of meter results falling within ±15 mg/dl (±0.83 mmol/liter) of the reference value for glucose concentrations below 100 mg/dl (5.6 mmol/liter) or within ±15% of the reference value for glucose concentrations at 100 mg/dl (5.6 mmol/liter) or higher. Both the Parkes consensus and the Clarke error grid analyses were used to evaluate the clinical significance of the deviations of the CONTOUR meter results from the laboratory glucose results.[3,4]

Results

Of 105 samples obtained from the subjects with diabetes, 74 met the blood glucose concentrations distribution requirements listed in **Table 2**. Twenty-six modified blood samples were added to the study for a total of 100 samples per the ISO 15197:2003 protocol.[1] Plasma glucose levels in the test samples ranged from 11 to 554 mg/dl (0.6–30.8 mmol/liter) and hematocrit levels ranged from 26% to 70%. As shown in **Table 3**, the CONTOUR BGMS exceeded the minimum acceptable accuracy criteria of ISO 15197:2003, with 99.3% [95% confidence interval (CI): 98.3%, 99.7%] of overall results falling within the criteria. When evaluated with the more stringent accuracy criteria, the CONTOUR BGMS had 96.7% (95% CI: 94.9%, 97.8%) of overall results that were within ±15 mg/dl

Table 2.
Distribution of Glucose Concentrations of Samples for System Accuracy Evaluation As Specified in ISO 15197:2003

Percentage of samples	Glucose concentration mg/dl (mmol/liter)
5	<50 (<2.8)
15	50 to 80 (2.8–4.3)
20	81 to 120 (4.4–6.7)
30	121 to 200 (6.7–11.1)
15	201 to 300 (11.2–16.6)
10	301 to 400 (16.7–22.2)
5	>400 (>22.2)

Table 3.
Percentage of CONTOUR Meter Results Falling Within ISO Minimum Acceptable Performance Criteria[a]

Number of samples within criteria	Percentage of readings within 20% or ±15 mg/dl (±0.83 mmol/liter)
596/600	99.3% (95% CI: 98.3%, 99.7%)
Glucose concentration (n)	Percentage of readings within specified error limits
≥75 mg/dl (492)	±20%
	99.2% (488/492)
<75 mg/dl (108)	±15 mg/dl
	100.0% (108/108)

[a] 95% of the individual glucose results shall fall within ±15 mg/dl (±0.83 mmol/liter) of the results of the manufacturer's measurement procedure at glucose concentrations <75 mg/dl (<4.2 mmol/liter) and within ±20% at glucose concentrations ≥75 mg/dl (≥4.2 mmol/liter).

(±0.83 mmol/liter) or ±15% of the reference value (**Table 4**). When grouped according to glucose levels below or above 100 mg/dl, 95.7% of results fell within ±15 mg/dl of the reference value for glucose concentrations below 100 mg/dl and 97.0% of results fell within ±15% of the reference value for glucose concentrations 100 mg/dl or higher (**Table 4**). Both Parkes consensus and Clarke error grid analyses[3,4] showed that 99.3% (596 of 600) of test results were within zone A, while 0.7% were within zone B, with no results in zones C, D, or E (**Tables 5** and **6**, **Figures 1** and **2**).

Table 4.
Percentage of CONTOUR Meter Results Falling Within ±15% of the Reference Value for Glucose Concentrations 100 mg/dl (5.6 mmol/liter) or Higher and Within ±15 mg/dl (±0.83 mmol/liter) of the Reference Value for Glucose Concentrations Below 100 mg/dl (5.6 mmol/liter)

Number of samples within criteria	Percentage of readings within 15% or ±15 mg/dl (±0.83 mmol/liter)
580/600	96.7% (95% CI: 94.9%, 97.8%)
Glucose concentration (*n*)	Percentage of readings within specified error limits
≥100 mg/dl (438)	±15%
	97.0% (425/438)
<100 mg/dl (162)	±15 mg/dl
	95.7% (155/162)

Table 5.
Summary of Parkes Consensus Error Grid Analyses of CONTOUR Meter Results

Zone	A	B	C	D	E
Frequency	596 out of 600	4 out of 600	0 out of 600	0 out of 600	0 out of 600
Percentage	99.3%	0.7%	0.0%	0.0%	0.0%

Table 6.
Summary of Clarke Error Grid Analyses of CONTOUR Meter Results

Zone	A	B	C	D	E
Frequency	596 out of 600	4 out of 600	0 out of 600	0 out of 600	0 out of 600
Percentage	99.3%	0.7%	0.0%	0.0%	0.0%

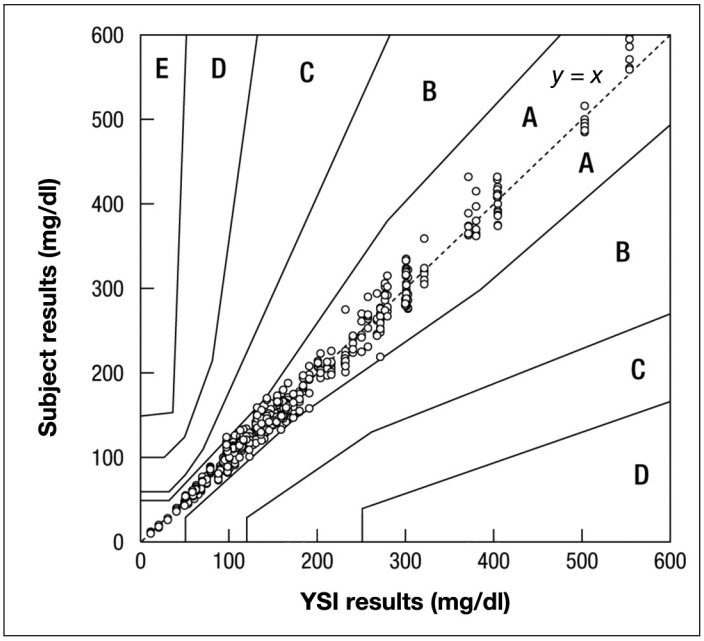

Figure 1. Parkes consensus error grid analysis of CONTOUR meter results.

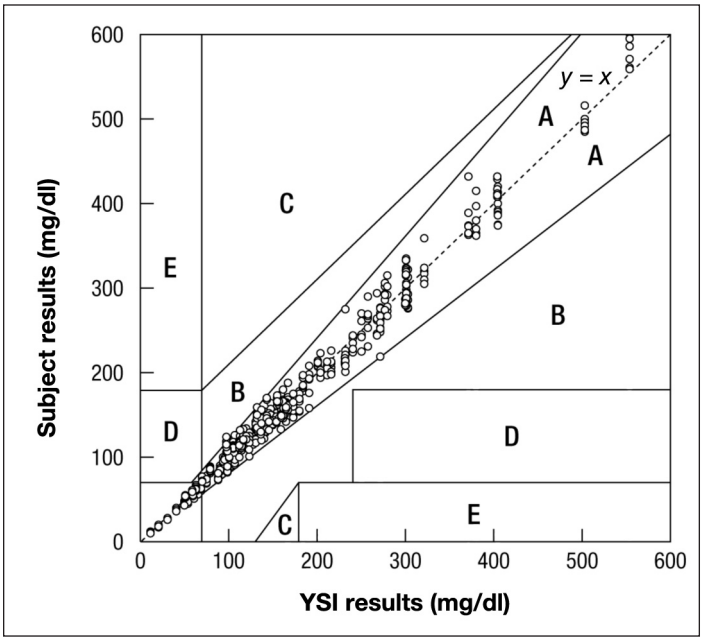

Figure 2. Clarke error grid analysis of CONTOUR meter results.

Discussion

According to the current version of ISO 15197:2003 Section 7, minimum acceptable accuracy requirements for BGMSs for self-testing in managing diabetes mellitus are as follows: 95% of the individual glucose results shall fall within ±15 mg/dl (±0.83 mmol/liter) of the results of a validated laboratory method at glucose concentrations

<75 mg/dl (<4.2 mmol/liter) and within ±20% at glucose concentrations ≥75 mg/dl (≥4.2 mmol/liter).[1] The criteria apply to "system accuracy evaluations in which users have received proper training, the device has been properly maintained, and required adjustment and control procedures have been followed in accordance with the manufacturer's instructions for use."[1] In other words, the accuracy evaluation described in Section 7 of the standard is a design verification activity intended to assess if the product meets the accuracy specifications set for it. Therefore, calibration errors are not expected to be captured in analytical accuracy studies nor are errors due to other procedural factors such as lack of proper meter maintenance or lack of proper hand washing and drying. Furthermore, studies addressing analytical accuracy are not designed to address successful strategies for self-monitoring of blood glucose or how monitoring data should be used to inform care in individual patients.

These concerns are best addressed in Section 8 of ISO 15197:2003, which describes user performance evaluations to demonstrate that users are able to operate the BGMS, given only the instructions and training materials routinely provided with the system and obtain valid glucose results.[1] However, specific accuracy criteria as provided in Section 7 are not provided in Section 8 of the current version of the standard.

Professional organizations and regulatory agencies have proposed a tighter accuracy standard for blood glucose monitoring devices than currently recommended by ISO 15197:2003.[5–7] Discussions in the health care industry have focused on updating the accuracy requirements for BGMSs with consideration of their intended use. ISO 15197:2003 applies to performance requirements for BGMSs intended for self-monitoring of blood glucose. The FDA currently applies the same accuracy criteria as ISO 15197 for both lay use and health care professional use, but it is possible that different standards will be developed for meters used in hospitals and long-term facilities compared with those indicated for self-monitoring in the home setting.[6] As guidelines and standards are updated, health care technology will be updated to meet these standards. However, it is also important that patients and health care professionals alike understand all factors that influence accuracy and that education be provided to help ensure that devices are used appropriately for optimal results.

In summary, the current study was conducted in accordance with Section 7 of ISO 15197:2003 and demonstrated that the CONTOUR BGMS exceeds the minimum acceptable accuracy requirements required by ISO 15197:2003. Furthermore, when data were analyzed using more stringent accuracy criteria of results being within ±15 mg/dl (±0.83 mmol/liter) or ±15% of the reference value, 96.7% of results fell within the more stringent criteria. Both Parkes consensus and Clarke error grid analyses showed that 99.3% (596 of 600) of test results were within zone A, while 0.7% were within zone B, indicating that deviations of glucose measurements from reference values had minimal or no effect on clinical action.

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Disclosures:

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