

Clinical evaluation of the eBsensor hand-held blood glucose monitoring system

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Abstract

Background: Home glucose monitoring system is increasingly recognized as an important tool for glycemic control. We evaluated the clinical performance of the eBsensor glucose monitoring system.

Methods: Fingertip capillary blood glucose concentrations from 282 subjects were measured using eBsensor glucose monitoring system and compared against predicate devices and the Yellow Springs Instruments (YSI) 2300 blood glucose analyzer. Accuracy and precision of the eBsensor glucose monitoring system were assessed using several methods. The comparative study between the eBsensor and 2 currently marketed monitoring systems was performed.

Results: The 282 eBsensor readings covered a wide range from 2.6 to 24.4 mmol/l. Deming regression and Pearson correlation analyses showed a linear relationship between the eBsensor readings and the YSI reference method (eBsensor=0.9496 YSI+0.4127 mmol/l; $r=0.98$). Error Grid analysis demonstrated that 100% of the eBsensor readings in clinically acceptable zones A and B. The CVs for the 6 lots of strips were within the satisfactory interval (<6%). The comparative study showed that the eBsensor readings correlated well with the OneTouch Ultra values ($r=0.97$) and the Glucocard II values ($r=0.97$).

Conclusions: eBsensor is a reliable glucose monitoring system which provides high accurate and precise glucose readings over a wide range of glucose concentrations.

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Keywords: Diabetes; Glucose monitoring system; Clarke Error Grid analysis; Glucose meter; Strip; Self-monitoring; Accuracy; Precision; Electrochemical

1. Introduction

Diabetes is a chronic disease associated with serious health complications including visual disability, kidney failure, neuropathy, and heart disease. The global number of people with diabetes was estimated to be 171 million in 2000 and 366 million in 2030 [1]. The total number of diabetes-associated deaths was estimated to be 2.9 million worldwide in 2000 [2]. Diabetes was ranked as the 6th leading cause of death in the U.S. in 2003 [3]. Previous

studies have shown that maintaining a normal or near-normal glucose level significantly prevents or delays some health complications for people with diabetes [4–7]. The development of blood glucose monitoring system permitted diabetic patients to monitor their glucose levels at home. This system was consequently recommended as an important component of routine care for diabetic patients to control their blood glucose levels [8–10].

There are many types of blood glucose monitoring systems currently available on the market. The clinical performance of many of these glucose monitoring systems has been reported [11–16]. Recently, eBsensor, a new 10-second hand-held blood glucose monitoring system (Visgeneer Inc., Hsinchu, Taiwan),

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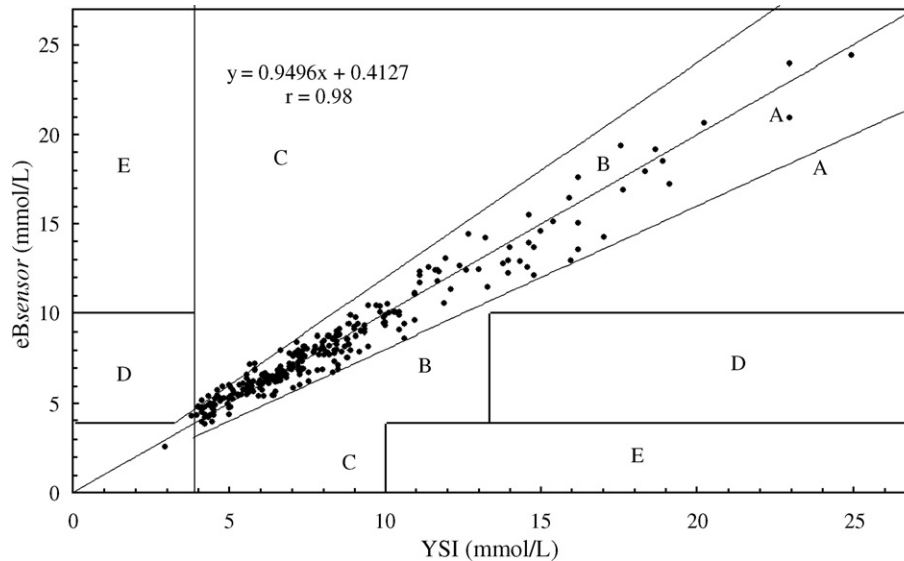


Fig. 1. Error Grid analysis of the eBsensor monitoring system. eBsensor readings were plotted against the YSI reference method.

has been introduced into the market. The objective of the present study was designed to evaluate the clinical performance of the eBsensor glucose monitoring system.

2. Materials and methods

2.1. Subjects and blood glucose measurements

This study comprised 282 patients with diabetes, who were all in the morning fasting state, attending the outpatient clinic of Wei-Gong Memorial Hospital (Miaoli, Taiwan). Of these participants, fingertip capillary blood glucose concentrations were obtained using eBsensor blood glucose monitoring system and 2 currently marketed monitoring systems, the Glucocard II (Arkray) and the OneTouch Ultra (LifeScan). All measurements were performed in the Department of Laboratory Medicine of Wei-Gong Memorial Hospital by the same trained technician according to the manufacturer's instructions to avoid errors made by patients. Immediately after fingerstick measurement, venous blood sample from each of the diabetic patients was drawn by a nurse. Plasma glucose concentrations of these samples determined by the Yellow Springs Instruments (YSI) 2300 blood glucose analyzer were served as the reference values. The hematocrits of the participants ranged from 30–55% were within the operative specification of the eBsensor. To evaluate the precision of the eBsensor glucose monitoring system, 6ty measurements at each of the 6 clinically relevant blood glucose ranges (2.8–3.1, 4.9–5.3, 7.8–8.7, 13.2–14.2, 18.8–19.9, and 24.3–25.4 mmol/l) were performed for the 6 lots of test strips using 6 eBsensor meters. To produce the 6 different glucose concentrations for

each lot of strips, venous whole blood samples from healthy volunteers were spiked before analysis. Analyses for this part of the study were performed over 2 weeks. All study protocols were reviewed and approved by the ethical committee of Wei-Gong Memorial Hospital.

2.2. Data analysis

The clinical accuracy of eBsensor was assessed by comparing the eBsensor readings with the YSI reference values using Pearson correlation analysis, Deming regression analysis, Clarke Error Grid analysis [17,18], and the percentage of readings within a defined range of deviation from the reference values. Using Pearson correlation and Deming regression analysis, the eBsensor readings versus reference values and 2 currently marketed monitoring systems (comparative study) were performed. For Clarke Error Grid analysis, the *x*-axis and the *y*-axis were defined as the YSI reference values and the eBsensor readings, respectively. The resulting graphic display of the Clarke Error Grid analysis was divided into five zones: 1) zone A: clinically accurate; 2) zone B: error greater than $\pm 20\%$ but would lead to benign or no treatment; 3) zone C: overcorrection of the true glucose value; 4) zone D: dangerous failure to detect and treat; 5) zone E: erroneous treatment. The percentage of readings within a defined deviation range ($<5\%$, $5\text{--}10\%$, $10\text{--}15\%$, $15\text{--}20\%$, and $>20\%$) of the reference values was analyzed for each of the glucose range (≤ 5.5 mmol/l, $5.6\text{--}11.1$ mmol/l, and ≥ 11.2 mmol/l). Precision of the eBsensor glucose monitoring system was assessed using coefficients of variation (CVs) calculated from the 60 measurements at each of the 6 different glucose concentrations.

3. Results

The present study included 282 patients, among whom 119 (42.2%) were females and 163 (57.8%) were males. The age of

Table 1
Number and percentage of eBsensor readings within a defined interval according to the different glucose concentration ranges

Glycemic ranges	Percentage deviation from the reference value					Total
	$<5\%$	$5\text{--}10\%$	$10\text{--}15\%$	$15\text{--}20\%$	$>20\%$	
≤ 5.5 mmol/L	20 (36.3%)	14 (25.5%)	15 (27.3%)	3 (5.5%)	3 (5.5%)	55
$5.6\text{--}11.1$ mmol/L	92 (50.5%)	49 (26.9%)	23 (12.6%)	14 (7.7%)	4 (2.2%)	182
≥ 11.2 mmol/L	17 (37.8%)	16 (35.6%)	8 (17.8%)	4 (8.9%)	0 (0.0%)	45
Total	129	79	46	21	7	282

Data are number or (%).

Table 2
The CVs (%) for measurements in series for six different glucose concentration ranges (mmol/L)

Lots of strips	2.8–3.1	4.9–5.3	7.8–8.7	13.2–14.2	18.8–19.9	24.3–25.4
Lot 1	4.32	3.81	4.25	3.52	3.4	3.44
Lot 2	5.56	4.89	3.35	3.34	3.83	3.93
Lot 3	4.74	4.4	4.32	3.51	2.62	3.14
Lot 4	5.24	4.0	3.86	3.42	3.43	4.6
Lot 5	5.84	5.11	4.86	5.92	4.47	5.26
Lot 6	4.17	5.43	5.02	4.37	3.77	3.12

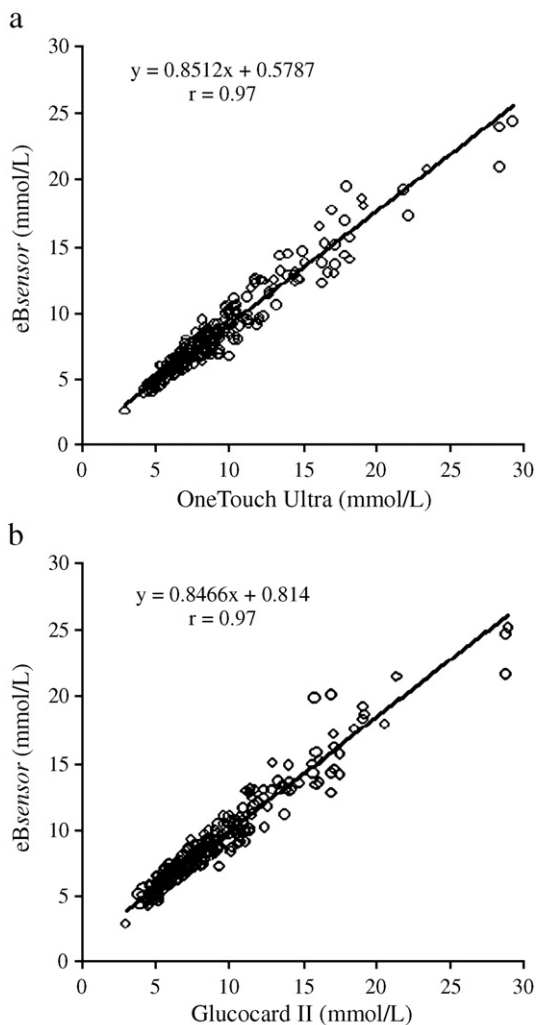


Fig. 2. Linear regression analysis of the eBsensor readings against the currently marketed monitoring systems. (a) OneTouch Ultra and (b) the Glucocard II.

the participants was from 18 to 87 y. The hematocrits of these participants were within the operative specification (30–55%) of the eBsensor. The 282 eBsensor readings covered a wide range of glucose concentrations from 2.6 to 24.4 mmol/l (55 readings (19.5%) ≤ 5.5 mmol/l, 182 readings (64.5%) 5.6–11.1 mmol/l, 34 readings (12.1%) 11.2–16.6 mmol/l, 9 readings (3.2%) 16.7–22.2 mmol/l, and 2 readings (0.7%) 22.3–27.8 mmol/l). Over the range of glucose readings, Pearson correlation and Deming regression analyses showed that eBsensor correlated well with the YSI values with the equation of $eBsensor = 0.9496 \text{ YSI} + 0.4127 \text{ mmol/l}$ and the 95% confidence intervals (CI) for the slope and intercept were 0.9262 to 0.9731 and 0.2015 mmol/l to 0.6239 mmol/l, respectively. Pearson correlation analysis showed that the correlation coefficient (r) was 0.98. Error Grid analysis showed that 275 readings (97.5%) fell within zone A and 7 readings (2.5%) fell within zone B (Fig. 1). All readings falling on zone B were near the A/B border. There were no readings in the C, D, or E zones.

Of the eBsensor readings, 97.5%, 90.1%, 73.8% and 45.7% were within $\pm 20\%$, $\pm 15\%$, $\pm 10\%$, and $\pm 5\%$, respectively, of the reference values. The total readings were divided into three

glucose ranges (≤ 5.5 mmol/l, 5.6–11.1 mmol/l, and ≥ 11.2 mmol/l) for further analysis (Table 1). In each of the glucose ranges, the percentage of readings deviating from the reference values within the 10% interval was found to be 61.8% (≤ 5.5 mmol/l), 77.4% (5.6–11.1 mmol/l), and 73.4% (≥ 11.2 mmol/l). The precision of the eBsensor glucose monitoring system is shown in Table 2. Of the 6 test glucose ranges (2.8–3.1 mmol/l, 4.9–5.3 mmol/l, 7.8–8.7 mmol/l, 13.2–14.2 mmol/l, 18.8–19.9 mmol/l, and 24.3–25.4 mmol/l), CVs for lot 1 to lot 6 were ranged from 3.4% to 4.32%, from 3.34% to 5.56%, from 2.62% to 4.74%, from 3.42% to 5.24%, from 4.47% to 5.92%, and from 3.12% to 5.43%. As compared to the currently marketed glucose monitoring systems, eBsensor correlated well with the OneTouch Ultra values ($eBsensor = 0.8512 \text{ OneTouch Ultra} + 0.5787 \text{ mmol/l}$, and $r = 0.97$; Fig. 2a) and with the Glucocard II values ($eBsensor = 0.8466 \text{ Glucocard II} + 0.814 \text{ mmol/l}$, and $r = 0.97$; Fig. 2b).

4. Discussion

eBsensor, a hand-held glucose monitoring system, was recently introduced into the self-monitoring diagnostic market. Using electrochemical detection technique, eBsensor was designed for rapid determination (10 s) of glucose concentrations over a wide range of glucose values (1.7 to 33.3 mmol/l) from a small amount (approximately 2.5 μl) of capillary whole blood sample. In order to determine if the eBsensor is an acceptable device for measuring blood glucose concentrations, the present study was aimed to evaluate the clinical performance of the eBsensor. The 282 eBsensor readings covered a wide range of glucose concentrations (2.6 to 24.4 mmol/l) suggesting that this study population was sufficient to represent a larger population of diabetic patients. Pearson correlation and Deming regression analyses showed that the eBsensor readings correlated excellently with the YSI reference values over the range of glucose concentrations measured. The Error Grid analysis showed that eBsensor glucose monitoring system had 100% of measurements in zones A and B suggesting that eBsensor is a clinically acceptable device for measuring blood glucose concentrations.

The percentage of deviation from the reference value is another relevant approach to determine the accuracy of the glucose monitoring system. It was recommended by the International Organization for Standardization (ISO) that 95% of the measurements should be within $\pm 20\%$ of the reference values for glucose concentrations higher than 4.2 mmol/l and within ± 0.83 mmol/l for glucose values under 4.2 mmol/l [19]. Our results showed that 97.5% of the eBsensor readings were within $\pm 20\%$ interval indicating that eBsensor met the accuracy criteria proposed by ISO. According to the recommendation of the American Diabetes Association (ADA), the acceptable range of deviation from laboratory reference values was limited within $\pm 5\%$ [20]. Although the clinical performance of the glucose monitoring systems has been reported regularly [11–16], none of the glucose monitoring systems was shown to be satisfied based on the ADA stringent criterion [21–23]. Another analysis approach has been proposed to group the glucose monitoring systems into good, acceptable, and unacceptable for

clinical use [24]. The “good” meters were defined as >60% of the readings within $\pm 10\%$ of the reference value. Thus, eB*sensor* should be classified as a “good” meter based on the result that eB*sensor* not only had 73.8% of the overall readings but also had 61.8%, 77.4%, and 73.4% of the readings in three different glycemic ranges within $\pm 10\%$ interval.

The CVs of the eB*sensor* at the 6 different glucose levels were within the satisfactory interval (<6%) suggesting that eB*sensor* monitoring system provided precise measurements. Furthermore, 2 currently marketed glucose monitoring systems, OneTouch Ultra and Glucocard II, were selected for comparison. Correlation and regression analyses showed that the eB*sensor* readings correlated well with the OneTouch Ultra and the Glucocard II values over the range of glucose concentrations measured. In conclusion, the present study demonstrates that eB*sensor* is a reliable glucose monitoring system providing high accurate and precise glucose readings and can be rated as “good meter”.

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