

A Simple Photometer as a Helping Device in Measuring Blood Glucose

Aryo Tedjo^{1*}, Erfi Prafiantini², Akmal P Suprpto³, Anwar S Ibrahim³,
Subari A Riyanto³, Dendi Priyanto³

1. Department of Medical Chemistry, Faculty of Medicine, Universitas Indonesia, Jakarta 10430, Indonesia
2. Department of Nutrition, Faculty of Medicine, Universitas Indonesia, Jakarta 10430, Indonesia
3. Department of Medical Physics, Faculty of Medicine, Universitas Indonesia, Jakarta 10430, Indonesia

*e-mail: aryo.tedjo@ui.ac.id

Abstract

Measurement of non-invasive blood glucose is one way to increase the frequency of self-monitoring of blood glucose (SMBG). For NIR reflectance spectroscopy, its application in non-invasive constrained by high value of standard error of prediction. The mean standard error of prediction was 25 mg/dL. Theoretically, NIR reflectance spectroscopy still can be used to predict blood glucose levels in certain conditions such as hypoglycemia (<55 mg/dL), controlled fasting blood glucose (FBG) (70-115 mg/dL), and hyperglycemia (>225 mg/dL), which the difference between the three conditions is more than 25 mg/dL. The results showed that there were significant differences in standards values of photometer measurement between controlled FBG and hyperglycemic conditions ($p = 0.002$). The results also showed that the photometer can be used to assist the monitoring of blood glucose in FBG under control and hyperglycemic conditions. It can be seen from the average percentage of the daily controlled FBG conditions in patients conducting SMBG in photometer-assisted compared to in patient only use SMBG once a day (28% versus 18%, $p = 0.344$).

Abstrak

Fotometer Sederhana sebagai Alat Bantu Pengukuran Glukosa Darah. Pengukuran glukosa darah secara non-invasif merupakan salah satu cara untuk meningkatkan frekuensi pemantauan glukosa darah mandiri (PGDM). Untuk yang berbasis spektroskopi reflektansi NIR, penerapannya secara non-invasif terkendala nilai standar *error of prediction* yang tinggi. Namun demikian metode ini secara teori masih dapat dipakai untuk memprediksi kadar glukosa darah pada kondisi tertentu seperti keadaan hipoglikemia (<55 mg/dL), gula darah puasa (GDP) terkendali (70-115 mg/dL), dan hiperglikemia (>225 mg/dL). Hasil penelitian menunjukkan bahwa terdapat perbedaan bermakna standar nilai pengukuran fotometer antara kondisi GDP terkendali dan hiperglikemia ($p = 0,002$). Fotometer yang digunakan dapat membantu pemantauan glukosa darah (PGDM pada kondisi GDP terkendali dan hiperglikemia). Hal ini dapat dilihat dari rata-rata persentase jumlah hari dengan kondisi GDP harian terkendali yang lebih besar pada PGDM yang dibantu dengan fotometer dibandingkan PDGM yang dilakukan hanya satu kali sehari (28% berbanding 18%, $p = 0,344$).

Keywords: fasting blood glucose, hyperglycemia, hypoglycemia, photometer, self-monitoring blood glucose

Introduction

Self-monitoring of blood glucose (SMBG) is an important component of modern therapy for diabetes melitus. SMBG has been recommended for diabetics and professional health officers in order to control and to avoid hypoglycemia. The objective of SMBG is to collect detailed information regarding blood glucose level in some specific times in order to get more constant blood glucose levels as a result of the

appropriate treatment and regimen. SMBG can also be used to help people in adjusting food consumption, physical activities, and the dose of insulin to raise the regular/every day glycemic control.

Most experts agree that the patient of Type-1 Diabetes (T1DM) who is under a treatment must monitor the blood glucose at least four times a day, especially during fasting, before meal, and before bed.¹ Davidson et al. (2004) showed a fact that there is a reverse

connection between the frequency of SMBG on a Type-1 Diabetes (T1DM) and the HbA1c score (the amount of glycosylated Hb).² In aretrospective research of more than 24,000 patients, Karter et al. (2000) found out that the increase of SMBG frequency has a strong correlation with the HbA1c score without considering the type of diabetes or the undergone treatment.³

The application of SMBG on diabetics nowadays has not shown a significant increase due to the lack of consensus on the time and frequency of blood glucose test.³ The hindering factors are finance, pain, and discomfort.^{4,5} This happens as SMBG is conducted by using a conventional glucometerdevice which is invasive.

Blood glucose measurement in a non-invasive way is one of the ways to increase the frequency of SMBG. There have been lots of methods or technologies that have been developed as a base for creating a non-invasive blood glucose measurement device. Some of these methods/technologies are *Near infrared spectroscopy (NIR)*, *Mid-infrared spectroscopy (Mid-IR)*, *Raman spectroscopy*, *Thermal spectroscopy*, *Ocular spectroscopy*, *Impedance spectroscopy*, *Optical coherence tomography*, *Temperature-modulated localized reflectance*, *Ultrasound* and *Iontophoresis*.⁶ However, up to 2007 there was only one non-invasive glucometer approved by FDA that has been available in the market.

For the NIR reflectance spectroscopy-based device, its non-invasive application is constrained by high value of standard error of prediction which is around 1.41 mmol/L (25 mg/dL).⁷ It means that this method is not reliable enough to measure the blood glucose in a non-invasive way. Yet, theoretically this method can still be applied to predict the level of blood glucose in a certain condition such as hypoglycemia (<55 mg/dL), controlled fasting blood glucose/FBG (70-115 mg/dL), and hyperglycemia (>225 mg/dL).

The objective of this research was to obtain a value standard for a simple photometer measurement used for blood glucose level in the condition of hypoglycemia, controlled FBG, and hyperglycemia. By knowing the standard it is hoped that the photometer used in this research can be used as a device for measuring blood glucose.

Methods

The simple photometer used in this research was the device that has successfully classified the types of breast cancer as well as skin cancer and it was also the result of a small scale research project (in vitro and in vivo on test animals).^{8,9} The photometer worked in the area that is near infrared (NIR).

The research was started by collecting diabetic patients (n=30), either those who had undergone regular treatment and those who took the blood sugar measurement test using the GlucoDr® at Puskesmas Kelurahan Koja, District of Koja, North Jakarta. After that they were asked for their availability to participate in this research. Ten of the patients were asked to check independently their own the blood glucose level of their whole blood capillary twice a day (before meal and two hours after lunch) for 14 days in a row using GlucoDr® Glucometer. They were also asked to measure the score of reflectance on their lower arm with the photometer (Figure 1a). This was meant as a calibration of the photometer to get the reflectance score that is equal to the blood glucose level of hypoglycemia, FBG, and hyperglycemia.

After each patient had the approximate photometer measurement on their blood glucose level (hypoglycemia, controlled FBG, or hyperglycemia), then we saw how well the photometer worked in helping diabetic patients in controlling their blood glucose level. For this purpose the patients were divided into 3 groups namely:

Group 1: Diabetic patients that regularly checked their own FBG level independently using glucometer (n=10).

Group 2: Diabetic patients that regularly checked their own FBG using glucometer independently supported with the measurement using photometer without any limitations.

Group 3: Diabetic patients that regularly checked their own FBG and blood glucose 2 hours after meal independently using glucometer (n=30).

Independent blood sugar measurement using glucometer can be done on the blood sample of whole blood capillary.

The activity of each group was conducted for 3 months (+/90 days). The evaluation of patients condition can be seen from the change of HbA1C score before and after the research was conducted, as well as the observation on the score of daily FBG.



Figure 1. The Way of Using the Photometer

Results and Discussion

The measurement score from the photometer compared to the range of blood glucose level in an acute condition (hypoglycemia/hyperglycemia) and the target of blood glucose control were conducted to all respondents in Group 2. A personal calibration measure had to be done as individual specifications such as skin colour and thickness, blood pressure as well as body temperature could affect the blood glucose measurement non-invasively with the method of NIR spectroscopy. The example of measurement on one of the research subjects can be seen on Table 1.

The mean of measurement using photometer in Group 1 & 2 had a significant difference $P = 0.002$. Based on Table 1 above it can be seen that the measurement value given by the photometer can significantly differentiate the condition of controlled FBG, hyperglycemia and hypoglycemia with the risk of patient X.

It means that the photometer can help patient X in monitoring his/her blood glucose level. For example, if patient X has the photometer score of 3.30 after having the measurement on his/her lower arm, it indicates that the patient is suffering from hyperglycemia.

From the result of measurement shown in Table 1, it can also be seen that the score of measurement with photometer has not been successful in predicting the condition of hypoglycemia on patient X. It means that one day the photometer measurement shows the result of less than 2.59 (the lowest of controlled FBG measurement), the patient will be suggested to monitor his/her blood glucose level using glucometer.

This result was the same as the previous research by Malin et al. (1999) that the non-invasive blood glucose level measurement with the NIR spectrometer method had an error of prediction standard value which was quite high around 25 mg/dL. This was what caused the inability to determine the standard value of photometer measurement on hypoglycemia or the lack of difference between the standard value of photometer measurement on hypoglycemia and controlled FBG, caused by the difference of value range between those two conditions (based on the measurement of blood glucose on whole

Table 1. The Score of Photometer (au) on Certain Ranges of Blood Glucose Level of Patient X (the Amount of Measurement, n=92)

Hypoglycemia	Controlled FBG	Hyperglycemia ³
<55 mg/dL	70-115 mg/dL	>225
Cannot be specified	2.7 (mean)	3.13 (mean)
Cannot be specified	0.9 (SD)	0.22 (SD)
	$2.78 \pm 0.19^*$	$3.13 \pm 0.22^*$

blood capillary). It was different from the controlled FBG and hyperglycemia where the range of difference was quite big which was around 100mg/dL, so that it resulted on a significant difference on those two conditions.

The evaluation of the patient's condition based on the change of the HbA1C score before and after the research can be seen in Figure 2.

In Figure 2 we can see that after conducting SMBG for 3 months (90 days), there was no effect on the change of the patient's HbA1C score. Based on the research done by I- Chin Huang et al. (2012) it was found out that the stability of HbA1C deviation standard value on Type 2 diabetic patient was influenced by the frequency of SMBG. It was also known that the frequency of SMBG had a negative correlation with the development of diseases that led to nephropathy, neuropathy, and retinopathy.

However, the research concluded that in order to reduce HbA1C, doing SMBG only was not enough. Changing lifestyle such as being on a diet, doing regular exercise, treatment, and body mass index (BMI) reduction program are some of the necessary things to do.¹⁰

An interesting thing that happened can be seen from the daily FBG score of the diabetic patient conducting SMBG. In general it can be seen that the way of conducting SMBG affected, although not significantly, the score of daily FBG. We can see it in Figure 3.

In Figure 3 we can see that patients who conducted SMBG twice a day (FBG and post prandial blood glucose, BGpp) have a bigger percentage on the number of days with the condition of controlled daily FBG than those who conducted SMBG once a day with or without the help of photometer (group 1 and 2). It is related to the research conducted by Parkin et al. (2009) showing

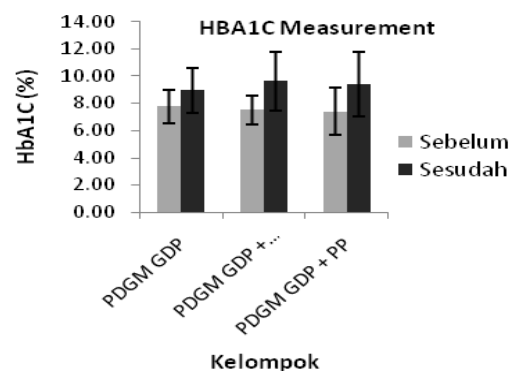


Figure 2. The Measurement of HbA1C Before and After the Research

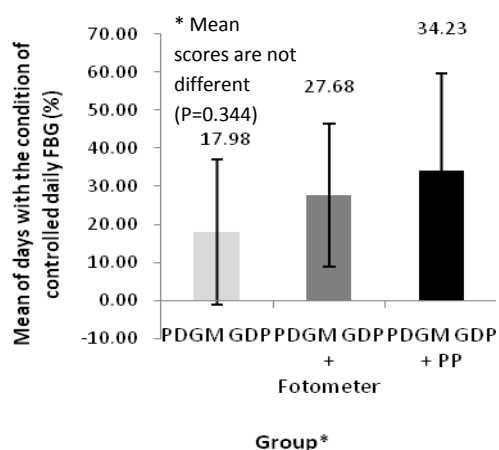


Figure 3. % of Days where Controlled Daily FBG is Achieved (70-115 mg/dL)

that the diabetic patient's glycemic condition such as normoglycemia as well as hypoglycemia were influenced by the frequency of SMBG.

It is also seen that the photometer used as a helping device for SMBG also affected, although not significantly, to the control of diabetic patient's FBG score that became the subject of this research.

Conclusions

The range of blood glucose level that can be predicted by using a simple photometer is between 70-115 mg/dL (controlled FBG) and >225 mg/dL (hyperglycemia). The value standard of photometer measurement in the controlled FBG is 2.78 ± 0.19 , while in the condition of hyperglycemia it is 3.13 ± 0.22 .

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