

# Noninvasive Glucose Measurement for Diabetes Mellitus Patients



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## Abstract

Nowadays, diabetes mellitus is a common disease in which patients have to measure the glucose levels in their body periodically in order to regulate their blood sugar. For this measurement most commonly used method is for patients to prick their fingers to draw blood, and use this blood for measurement. However this method is an invasive and painful method, and the patients have to do this measurement regular intervals daily. Today however, there are a lot of research on noninvasive methods and this way both a painless measurement can be made and the blood glucose levels of the patients can be regularly controlled by making the measurement continuous.

**Keywords:** diabetes; glucose measurement; noninvasive

## Mini Review

Diabetes mellitus, commonly known as diabetes is a chronic disease in which the body cannot produce enough insulin or cannot use the insulin. Without insulin, the body cannot regulate blood sugar and this causes high glucose levels in blood [1]. Raised glucose levels can cause some permanent damages in tissues and organs. For this reason, people with diabetes need to regularly measure their blood sugar levels and inject the necessary amount of insulin to their body.

Today, most common method for blood glucose measurement is done by pricking the finger and taking some blood to test. This method is painful and since it is an invasive method, it can result in infections. And patients have to do these measurements several times daily. Because of these reasons, researchers have been working on a non-invasive solution for glucose measurement for years. Despite some developed devices, there is not a product with enough accuracy in market today.

Near-infrared spectroscopy, most commonly attempted method of non-invasive glucose measurement, uses near-infrared (NIR) region (700 nm to 2500 nm) of the electromagnetic spectrum. Light in this region can penetrate tissue more than other wavelengths. The measurement on this method can be done by using reflection [2], transmission [3] or Spectral analysis [4]. There are no characteristic bands for glucose in NIR. Therefore, the information obtained by the measurement can easily be affected from other factors and for correct glucose levels, some other measurements or algorithms may be needed.

Another disadvantage for this method is the need for individual calibration [5].

Mid-infrared spectrum which uses 2.5 to 25 $\mu$ m wavelength region is another possible region for glucose measurement and it has characteristic bands for many molecules. But light in mid-infrared region cannot travel very far into tissue and therefore is not a very effective way for glucose measurement in blood [5].

Another spectroscopic method, Raman spectroscopy uses the Raman scattering, which is inelastic scattering of photons of an excited source. Use of this technique in glucose measurement reduces the effect of high water absorption in mid-infrared frequencies [6]. Raman spectroscopy can be considered an efficient way of glucose measurement but the detection of Raman scattering is a very difficult process and therefore it is not suitable for everyday use.

The acoustic wave propagation of optical wave applied materials is defined as the photo-acoustic effect. Applying an optical wave to a substance causes the molecules in the substance to emit heat. This propagation leads to thermoelastic expansion and acoustic wave formation. If for measurement the wave lengths that glucose can absorb are used, glucose estimation can be done by measuring the obtained photoacoustic waves [7]. Although the basic absorption band of glucose is in the mid-infrared region, for this method near-infrared waves are used, because absorption band of water is also found in this region. The near infrared band also increases the penetration into tissue.

In the optical polarimetry method, the rotation and amplitude change that happens to the linear polarized light as it travels through molecules is used. Because the glucose amount in blood is too low, the change to light is very low and it is very difficult to measure. Therefore, in order to reduce the effect of skin, in this method aqueous humor is generally used. However, the glucose concentration in this fluid does not change with blood glucose immediately. In addition, since the molecules with the same structure as glucose can affect the light in the same way, the rate of error is high [8].

Millimeter waves are electromagnetic waves with wave lengths between 1 and 10 mm in the extremely high frequency range. Studies of measuring glucose concentration with millimeter waves in recent years are based on the amount of glucose present in the complex permittivity of the blood. In these studies, complex permittivity is calculated by using the reflection coefficient. The reflection coefficient can be measured with the help of open-ended coaxial cable and network analyzers. Also, the resonance frequencies of the solutions vary in proportion to the glucose intensities in the solutions [9]. In another study on this subject, a portable millimeter-wave oscillator and a transceiver CMOS circuit design was used to measure blood sugar measurement by conduction on ear. This study was done on animals and it was found that the amount of millimeter wave absorbed by the ear is in relation to the glucose concentration [10].

There are studies on blood glucose measurement with impedance sensors considering that the dielectric properties in blood are changed depending on the amount of glucose present. The impedance of these sensors varies depending on the shape of the sensor and the area around it, such as the properties of blood, skin and tissues [11]. Microwave resonators can be used as impedance sensors. Circular spiral resonators are usually used for this purpose in studies. In the impedance measurement method, individual calibrations must be performed as each person has different body impedances. It should also be noted that body impedance can vary with parameters such as blood pressure, temperature and pulse rate [12].

Iontophoresis is an approach to increase absorption of polar and charged molecules across the skin using electric current. From this method reverse iontophoresis, another method to measure glucose levels using subcutaneous glucose extracted with electric current has been developed. This method assumes the measured levels are proportional with glucose levels in blood. However, when the method is first applied this measurement is irrelevant to blood glucose levels and several hours of stabilization period is required for correct results [13]. There are commercial products developed using this method. However, as the product continuously applies electrical current through the skin, it causes irritation to the area of use and the measured glucose values are not of sufficient sensitivity [5]. And for this reason this product is no longer available.

The general advantages and disadvantages of the methods mentioned in this article are summarized below with the help of a table.

**Table 1:** Comparison of non-invasive measurement methods.

Method	Advantages	Disadvantages
NIR	Low cost, easy to design.	Insufficient accuracy.
Raman spectroscopy	Precise measurement. Adverse effect of water is reduced.	High cost, special detector required.
Photoacoustic spectroscopy	Precise measurement. Extended applicable wavelength range.	Easily affected by environmental variables.
Optical Polarimetry	Measurement made from the aqueous humor, less molecules to cause errors.	Difficult to measure, unmeasurable over skin.
Millimeter waves	Isolated measurement by focusing on important frequencies for glucose.	Easily affected by environmental variables.
Impedance measurement	Low cost, easy to design.	Easily affected by environmental variables.
Reverse iontophoresis	Measures directly through the glucose molecule.	Causes irritation

## Conclusion

Many different methods are currently being investigated in order to measure glucose non-invasively for Diabetes Mellitus Patients. However, until now there has been no product accepted on the market using any method due to various reasons such as difficulty in measuring with sufficient precision or difficulty in using.

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