



Non-Invasive Blood Glucose Measurement

Akesh Govada¹, Ch Renumadhavi², K B Ramesh³

PG Scholar, Biomedical Signal Processing & Instrumentation, Dept of IT, RVCE, Bangalore, India¹

Associate professor, Biomedical Signal Processing & Instrumentation, Dept of IT, RVCE, Bangalore, India²

Associate professor, Biomedical Signal Processing & Instrumentation, Dept of IT, RVCE, Bangalore, India³

Abstract: Diabetes has emerged as a major healthcare problem in India. Today Approximately 8.3 % of global adult population is suffering from Diabetes. India is one of the most diabetic populated country in the world. Today the technologies available in the market are invasive methods. Since invasive methods cause pain, time consuming, expensive and there is a potential risk of infectious diseases like Hepatitis & HIV spreading and continuous monitoring is therefore not possible. Now a days there is a tremendous increase in the use of electrical and electronic equipment in the medical field for clinical and research purposes. Thus biomedical equipment's have a greater role in solving medical problems and enhance quality of life. Hence there is a great demand to have a reliable, instantaneous, cost effective and comfortable measurement system for the detection of blood glucose concentration. Non-invasive blood glucose measurement device is one such which can be used for continuous monitoring of glucose levels in human body.

I. INTRODUCTION

Diabetes is one among the supreme health challenges of the current century. Glucose concentration changes in the blood in any direction i.e. increase or decrease in blood glucose concentration proves fatal for the patient. The acceptable range of glucose concentration is from 70 mg/dL (milligram of glucose in 100 millilitres of blood) to 110 mg/dL or 3.9 to 6.0 mM/L. But soon after eating glucose concentration of a person may rise to a level up to 140 mg/dL. The technologies available in the Indian market today require a patient to take blood samples and measure using chemical reactions which are both painful and costly. So there is a need of blood glucose measuring device which may provide continues monitoring of blood glucose concentration non-invasively.

juvenile diabetes, or early-onset diabetes. People usually develop type 1 diabetes before their 40th year, often in early adulthood or teenage years. Type 1 diabetes is nowhere near as common as type 2 diabetes. Approximately 10% of all diabetes cases are type 1. Patients with type 1 diabetes will need to take insulin injections for the rest of their life. They must also ensure proper blood-glucose levels by carrying out regular blood tests and following a special diet. Between 2001 and 2009, the prevalence of type 1 diabetes among the under 20s in the USA rose 23%, according to SEARCH for Diabetes in Youth data issued by the CDC (Centres for Disease Control and Prevention).

1.1 THEORY AND FUNDAMENTALS

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Diabetes mellitus, or simply diabetes, is a group of metabolic diseases in which a person has high blood sugar, either because the pancreas does not produce enough insulin, or because cells do not respond to the insulin that is produced. It is also referred as breakdown of ability to regulate the amount of glucose (sugar) in the blood stream. This high blood sugar produces the classical symptoms of polyuria (frequent urination), polydipsia (increased thirst) and polyphagia (increased hunger).

There are three main types of diabetes mellitus (DM).

- 1) Type 1 Diabetes
- 2) Type 2 Diabetes
- 3) Gestational Diabetes

1. Type 1 Diabetes:

The body does not produce insulin. Some people may refer to this type as insulin-dependent diabetes,

2. Type 2 Diabetes:

The body does not produce enough insulin for proper function, or the cells in the body do not react to insulin (insulin resistance). Approximately 90% of all cases of diabetes worldwide are of this type. Some people may be able to control their type 2 diabetes symptoms by losing weight, following a healthy diet, doing plenty of exercise, and monitoring their blood glucose levels. However, type 2 diabetes is typically a progressive disease - it gradually gets worse - and the patient will probably end up have to take insulin, usually in tablet form. Overweight and obese people have a much higher risk of developing type 2 diabetes compared to those with a healthy body weight. People with a lot of visceral fat, also known as central obesity, belly fat, or abdominal obesity, are especially at risk. Being overweight/obese causes the body to release chemicals that can destabilize the body's cardiovascular and metabolic systems. Being overweight, physically inactive and eating the wrong foods all contribute to our risk of developing type 2 diabetes. Drinking just one can of (non-diet) soda per day can



raise our risk of developing type 2 diabetes by 22%, researchers from Imperial College London reported in the journal *Diabetologia*. The scientists believe that the impact of sugary soft drinks on diabetes risk may be a direct one, rather than simply an influence on body weight. The risk of developing type 2 diabetes is also greater as we get older. Experts are not completely sure why, but say that as we age we tend to put on weight and become less physically active. Those with a close relative who had/had type 2 diabetes, people of Middle Eastern, African, or South Asian descent also have a higher risk of developing the disease.

3. Gestational Diabetes:

This type affects females during pregnancy. Some women have very high levels of glucose in their blood, and their bodies are unable to produce enough insulin to transport all of the glucose into their cells, resulting in progressively rising levels of glucose. Diagnosis of gestational diabetes is made during pregnancy. The majority of gestational diabetes patients can control their diabetes with exercise and diet. Between 10% to 20% of them will need to take some kind of blood-glucose-controlling medications.

Scientists from the National Institutes of Health and Harvard University found that women whose diets before becoming pregnant were high in animal fat and cholesterol had a higher risk for gestational diabetes, compared to their counterparts whose diets were low in cholesterol. Other forms of diabetes mellitus include congenital diabetes, which is due to genetic defects of insulin secretion, cystic fibrosis-related diabetes, steroid diabetes induced by high doses of glucocorticoids, and several forms of monogenic diabetes.

Acute complications include diabetic ketoacidosis and nonketotic hyperosmolar coma. Serious long-term complications include cardiovascular disease, chronic renal failure, and diabetic retinopathy (retinal damage). Adequate treatment of diabetes is thus important, as well as blood pressure control and lifestyle factors such as stopping smoking and maintaining a healthy body weight.

II. CURRENT RESEARCH ABOUT NON-INVASIVE METHODS

Non-invasive blood glucose monitoring assays have been studied and explored by many researchers around the world over the years and the most commonly approaches are by using optical detection or optical scanning methods, i.e., polarimetry, Raman spectroscopy, photo acoustic spectroscopy, Mid-Infrared (MIR) spectroscopy using an Attenuated Total Reflection (ATR) prism, and Near-Infrared (NIR) spectroscopy. NIR spectroscopy is used in the development of a non-invasive blood glucose concentration monitoring system in this study. The advantages of NIR spectroscopy over MIR spectroscopy include greater penetration depths (shorter

wavelength) and less background interference due to water absorption. The greater penetration depths are preferred for monitoring blood glucose in capillaries and glucose in interstitial fluid and tissue. Besides, NIR spectroscopy also offers advantages over Raman spectroscopy, such as higher SNR and broadband light source is used instead of the highly monochromatic source necessary for Raman spectroscopy. Non-invasive determination of the glucose also promotes regular testing, adequate control, complications reduction and consequently health care cost reduction.

Near infrared spectroscopy (NIR): The light focused on the body is partially absorbed and scattered, due to its interaction with the chemical components within the tissue. Glucose concentration could be estimated by variations of light intensity both transmitted through a glucose containing tissue and reflected by the tissue itself [1]. *Advantage:* High accuracy. Measuring signal has high energy compared with MIR spectroscopy [11].

Raman spectroscopy is based on the use of a laser light to induce oscillation and rotation in molecules & consequent emission of scattered light influenced by this molecule vibration, which depends on the concentration of the glucose molecule [6]. *Advantage:* Fixed wavelength lasers at relatively low cost can be used. The limitations are related to instability of the laser wavelength and intensity, and long spectral acquisition times [6].

Fluorescent spectroscopy: This technique analyses the fluorescence from the sample. It was also proved that fluorescence intensity was dependent upon glucose concentration in the solution. *Advantage:* Light in the visible spectrum can be used and more adequate for studying fluorescence of tissues. *Limitations:* In tissues, the use of ultraviolet light could lead to strong scattering phenomena, in addition to fluorescence [6].

Polarization Change: It is based on the phenomenon that occurs when polarized light transverses a solution containing optically active solutes (such as chiral molecules). Glucose is a chiral molecule, and its light rotation properties have been known for a long time. Indeed, investigation of the polarization changes induced by glucose is reported to be the first proposed non-invasive technique for glucose measurement in humans. [5] *Advantage* of Polari-metric technique is that this can make use of visible light, easily available. *Limitations* are this technique is sensitive to the scattering properties of the investigated tissue, since Scattering depolarizes the light [5].

Mid-infrared spectroscopy is based on light in the 2500–10,000nm spectrums. The physical principle is similar to that of NIR. When compared to NIR, however, due to the higher wavelengths, Mid-infrared exhibits decreased scattering phenomena, and increased absorption [1, 11]. *Advantage:* Mid-infrared compared to NIR is that the Mid-infrared bands produced by glucose, as well as other compounds, are sharper than those of NIR, which are often broad and weak. *Limitations:* One strong limitation is the poor penetration.



III. BASIC PRINCIPLE

Beer-Lambert Law is the major principle involved in absorbance measurement and determination of concentration. It states that absorbance of light through a solution is proportional to the concentration and the path length of light

Qualitatively, the absorbance is expressed by Beer Lambert Law as follows:

$$T=I/I_0 \quad \text{-----} \quad (1)$$

Transmittance of the sample can be measured directly by taking the strength of the wavelength measured and dividing it by initial strength. The absorbance can then be calculated as in the following:

$$A= -\log (T) \quad \text{-----} \quad (2)$$

Absorbance is also equal to abc , which is the absorptivity coefficient (a) multiplied by the path length (b) multiplied by the concentration (c). The actual glucose level will be measured against a baseline wavelength which changes little with glucose levels, or λ_1 . The wavelength which varies with glucose levels will be λ_2 . The actual concentration will be

$$A(\lambda_1)-A(\lambda_2)=bc(a_1-a_2) \quad \text{-----} \quad (3)$$

With a known glucose level, a_1-a_2 can be calculated from the equation (3). Once this is known, all other concentrations measured can be calculated as a ratio of the initial concentration, where a_1-a_2 and b are both constants. The concentration ratio is then checked against the known concentrations of the glucose solutions to determine the characteristic equation of the ratio to the actual concentration.

III. METHODOLOGY

Several techniques have been proposed for Non-invasive in vivo monitoring of blood and tissue glucose in recent years. NIR spectroscopy for determining the blood glucose concentration non-invasively has been demonstrated by many groups and much progress has been made in the past few years. Optical sensors can be used to measure the NIR spectra of the human finger. A NIR spectrometer with a fiber optic accessory can be used for the non-invasive measurement of blood glucose.

The proposed system has been equipped optical sensor, signal conditioning, ADC, microcontroller and LCD display. NIR signals are passed through the fingertip with and without blocking the blood flow. The received reflected signal is amplified and filtered, using a precision amplifier and a low pass filter. So for this Signal conditioning section is used which consists of a preamplifier and a low pass filter. An ADC buffer is used to perform the ADC conversion of the received signal from signal conditioning section. The microcontroller unit used to convert the values into corresponding blood glucose value, which is then displayed on LCD.

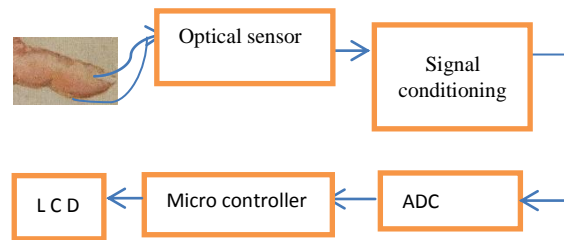


Fig 1: Block diagram of Non-invasive blood glucose measurement system

The technology is based on the direct effect of glucose on the scattering properties of the organ. Glucose decreases the mismatch in refractive index between scatterers and their surrounding media, leading to a smaller scattering coefficient and, consequently, a shorter optical path. As a result, with the growing concentration of glucose, fewer photons are absorbed and the light intensity increases.

IV. RESEARCH GAP

Most of the methods available in present market to measure blood glucose are invasive methods. Non-invasive blood glucose monitoring assays have been studied and explored by many researchers around the world over the years and the most commonly approaches are by using optical detection or optical scanning methods., i.e., polarimetry, Raman spectroscopy , photoacoustic spectroscopy , Mid-Infrared (MIR) spectroscopy using an Attenuated Total Reflection (ATR) prism , and Near- Infrared (NIR) spectroscopy. Presence of many other interfering light absorbers, Heterogeneous glucose distribution in skin are some of the drawbacks. Present non-invasive blood glucose monitoring system is to improve the accuracy and useful for continuous monitoring in home as well as health care centres.

V. SCOPE OF THE PROJECT

A non-invasive blood glucose measurement is used to measure blood glucose levels without taking blood. Till now the technologies available are pricking blood from body which is painful, costly and not used for continuous monitoring. So non-invasive blood glucose measurement is used for continuous monitoring of glucose levels in blood which is very much needed in present market.

VI. CONCLUSION

In India the most popular method for the measurement of the blood glucose is invasive method in which most of these involve drawing blood through a small pinprick and placing a drop on a test strip. This is risk of infection, costly and discomfort for the patients. Our Aim is to provide an innovative idea to solve the existing problems, which patients are facing with the current glucose meter technique. This can be used for continuous monitoring of glucose in home by the patients which is low cost and high accuracy.



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