Abstract: Diabetes has evolved as one of the principal health care epidemics of the modern era. At present, the widely used method of self-monitoring of blood glucose (SMBG) involves determination of blood glucose concentration with specific devices using chemical analysis of blood samples taken by puncturing the finger or the forearm. Although SMBG has revolutionized the management of diabetes, discomfort and inconvenience of this invasive technique are frequent barriers for effective compliance and therefore, optimum management. The aim of this paper is to discuss the feasibility study and design issues of non-invasive glucose measurement technique using optical method which would be able to overcome the current limitations.

1. INTRODUCTION

Diabetes is the biggest health challenge of the 21st century. It is the major cause of blindness, obesity, ageing population, heart disease, stroke, amputations and renal failure in the world. Diabetes affects the body’s ability to produce or utilize insulin, a hormone that is needed to properly process blood glucose. As a result, diabetics must regulate their own blood sugar levels through diet and insulin injections. The key point in the regulation of blood sugar is the accurate measurement of the blood sugar level.

Currently, blood glucose can only be monitored through the use of invasive techniques. Most of these involve drawing blood through a small pinprick and placing a drop on a test strip. These measurements must be taken several times, generally around half a dozen, a day by those with diabetes. The risk of infection and measurement inaccuracy are present with all of the invasive techniques. In addition, due to the discomfort caused by the pinprick and the resultant bruising, many diabetics do not check their glucose levels as often as recommended and as a result increase their chance of having sugar shock or diabetic coma. Appropriate therapy of diabetes such as frequent self-monitoring of blood glucose by patients, however, can reduce the complications of diabetes by up to 75%.

A truly non-invasive [1, 2] glucose-sensing device could revolutionize diabetes treatment by leading to improved compliance with recommended glucose levels. Non-invasive monitoring of blood glucose offers many advantages, which avoid pain and discomfort from frequent finger-pricking. This paper deals with the feasibility of the measurement of blood glucose through various non-invasive techniques, which involve light absorption and phase change in the visible and near-infrared wavelengths.

Authors have mainly described the method of NI blood glucose determination and the issues regarding components such as incident light wavelength, receiver point, optical model for biological tissue and system design.

2. CURRENT RESEARCH ABOUT NON-INVASIVE METHODS

Noninvasive techniques [3-8] include near-infrared and Raman spectroscopy, polarimetry, light scattering, photoacoustic spectroscopy, polarization technique, mid infrared spectroscopy etc.

In near infrared spectroscopy (NIR) [9-11] absorption or emission data in the 0.7 to 2.5 µm region of the spectrum are compared to known data for glucose. For Raman spectroscopy, laser light is used to induce emission from transitions near the level excited. Photo acoustic spectroscopy deals with the laser excitation of fluids to generate an acoustic response and a spectrum as the laser is tuned. In scatter technique, the scattering of light can be used to indicate a change in the material being examined. For polarization technique, the...
The presence of glucose in a fluid is known to cause a polarization preference in the light transmitted. Whereas mid infrared spectroscopy deals with absorption or emission data in the 2.5 µm - 25 µm regions to examine and quantitate glucose in a fluid.

In the current paper, the problem and technical analysis of non-invasive (NI) blood glucose measurement at the present time are discussed. Authors preliminarily aim at the method of NI blood glucose determination and the original concept of measuring system.

### 3. DESIGN ISSUES

Detecting the signal induced by glucose is quite difficult because the background signal is dynamic and complex. Absorbance spectra that are measured from skin tissue are influenced not only by water, albumin, globulin, hemoglobin, and triglyceride but also by environmental factors such as temperature and vapor levels. Another major design issue related to NI blood glucose measurement [12] is calibration due to varying amounts of protein, fats and water in different people. The actual measurement of blood glucose through absorption in the visible to low near infrared region has the problems of interference through protein and fat absorption. Measurement in the near infrared region has the problems with interference from water. Although, satisfactory prediction results have been obtained by most groups in their published papers, problems remain to be unsolved in order to achieve reliable and precise results. There are several critical obstacles preventing from the success of measuring glucose non-invasively.

There are many potential sources of interference in the present measurement technique. The stability relies on a constant optical coupling to skin, which is difficult to maintain unless the patient is lying still. Perspiration beneath the probe can also degrade this coupling.

Besides profound methodological problems with the calibration methods necessary for the analysis of absorption measurements, any spectrometric estimation of glucose in skin faces a number of problems mainly significant scattering of light, heterogeneous distribution of light absorbing and light scattering structures which additionally are variable over time (in part due to changes in blood supply and blood oxygenation), unknown path length of light in skin, heterogeneous glucose distribution in skin, presence of many other interfering light absorbers (like water) in much higher concentrations, very similar absorption spectra of water and glucose, temperature dependence of light absorption.

The problems listed highlight the design issues relating complexity of noninvasive blood glucose estimations.

### 4. WORKING PRINCIPLE

The proposed system is based on the principle of absorbance transmittance photometry. The value of absorption of light energy is dependent on the number of molecules present in absorbing material. Thus, intensity of light energy leaving the absorbing substance is used as an indication of concentration of that particular substance.

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

\[ T = \frac{I}{I_0} \]  

(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:

\[ A = -\log(T) \]  

(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 \( \lambda_1 \). The wavelength which varies with glucose levels will be \( \lambda_2 \). The actual concentration will be

\[ A(\lambda_1) - A(\lambda_2) = bc(a_1 - a_2) \]  

(3)

With a known glucose level (say 400 mg/dl), \( a_1 - a_2 \) 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.

5. METHODOLOGY

Several techniques have been proposed for noninvasive 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 fibers can be used to measure the NIR spectra of the human forearm. 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 light source, optical fiber and PIN photodiode. The light returned from the tissue has been received by the fiber optic and collected by the photodiode. Then an ADC is used to convert the analog signal to digital. A microcontroller based circuitry converts the values into corresponding blood glucose value, which is then displayed on LCD.

The probe contains light sources and detectors operating in the red/near-infrared (RNIR) spectral region and pneumatic cuffs that produce oversystolic pressure to occlude blood flow has a special adaptive mechanism for easy positioning and a suitable grip for a wide range of palm sizes, thus assuring user convenience and compliance.

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.

6. CONCLUSIONS

Continuous glucose monitoring (CGM) provides additional temporal information, such as trends, magnitude, duration, and frequency of glucose level fluctuations. This information can aid in the identification and prevention of unwanted hypo and hyperglycemic episodes. Furthermore, it can activate alarm signals for extreme glucose levels; decrease the nursing workload in tight glycemic control. CGM can also adjust therapy, quantify the response in diabetic therapy trials, and monitor conditions where tight control without hypoglycemia is sought (Intensive Care Units, gestational diabetes, pediatric diabetes).

This study demonstrated the feasibility study and design issues to monitor blood glucose concentration noninvasively in human subjects. The overall investigation into non-invasive measurement techniques for blood glucose indicates that it is a non-trivial problem. Direct absorption measurement is extremely difficult if it is even possible, and the use of interferometric techniques would need to take into account factors such as tissue thickness (i.e. require calibration for an individual). Despite the problems, it is a viable technique for the measurement of glucose concentrations in the blood and requires further investigation.

REFERENCES


