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Proposed Approach on Non Invasive Detection of Diabetes by Spectral Analysis of Absorbed, Reflected and Transmitted Light of Different Wavelengths by the Blood

Olusoji Amos Ogunbode[1]*, Adegbenro Sunday Ajani[2] , Oluwatayo Sandra Ajani[3]

[1]*Ladoke Akintola University of Technology, Department of Pure and Applied Physics, P.M.B 4000 Ogbomoso, Oyo State, Nigeria

[2]Kwara State University, Department of Physics and Material Sciences, Malete, Ilorin, Nigeria

[3]Ladoke Akintola University of Technology Teaching Hospital, Ogbomoso, Nigeria

*aoogunbode19@pgschoollautech.edu.ng[1]**

adegbenro.ajani@kwasu.edu.ng[2], sadratayo@yahoo.com[3]

Abstract: This investigation pinpoints the major requirements for the development of a clinically reliable devices for blood glucose monitoring. Noninvasive devices for blood glucose have been employed to monitoring blood glucose with the effort to give a better life to diabetic patients by developing easy blood glucose measurement instruments, with little fear of medical risk and mortality related to diabetes. Optically based methods for noninvasive approaches have provided great development to blood glucose monitoring. Various researchers and companies have designed and developed noninvasive blood glucose monitoring devices to detect diabetes, and this paper describes their working principles, importance and limitations, so as to give room for more comfortable designs. It is important to understand that noninvasive monitoring will never be achieved without good calibration approach. At this point, we are far away from reaching the aim of noninvasive blood glucose measurement, with many technical problems yet to be resolved.

Keywords: Noninvasive; blood glucose; diabetes.

Introduction

A statistical analysis by the World Health Organization (WHO) shows that more than 422 million people have to live with diabetes [1].Diabetes caused 1.5 million deaths in 2015, another 2.2 million deaths were directly attributable to high blood glucose, and almost half of all deaths attributable to high blood glucose occur before the age of 70 years. WHO predicted that diabetes will be the 7th leading cause of death in 2030[1]. Early diagnosis and continuous management are essential to patients to ensure a healthy life and to prevent circulatory problems and other diseases caused by diabetes; such as kidney failure, heart disease and blindness [1, 2].

Current practices for diabetes management rely on monitoring blood glucose. Patient has to prick their finger for a drop of blood multiple times a day, about 1800 times per year to check glucose levels. Furthermore the reports of blood-borne infection have been reported with these invasive glucose sensors [24, 25]. Consequently, new techniques have been employed to develop a noninvasive device for blood glucose monitoring, and the effort to give a better life to diabetic patients by developing their comfort for easy blood glucose monitoring, with little fear of medical problem and health conditions related to this metabolic disorder. With this noninvasive approach, the continuous process of monitoring blood glucose will be done in large numbers. For these reasons, at present the noninvasive technology is the most demanding research topic in biomedical science and its related areas [3, 4, and 5].

This research paper is divided into sections: Section 1 provides brief facts about World Health Organization statistical analysis on diabetes, invasive and noninvasive blood glucose monitoring techniques. Section 2 describes the principles and limitations for noninvasive blood glucose monitoring. Section 3 discuses the challenges facing noninvasive detection of blood glucose. Section 4 explains the mathematical model used for the blood glucose measurements. Section 5 describes principle of measurement. Section 6 illustrates the proposed methodology. Section 7 provides the conclusion, recommendation, acknowledgement, and references.

The Modern Development of Optical Technology Methods for Monitoring Blood Glucose (Principle and Their Limitation)

Raman Spectroscopy

Principle: It involves the use of the scattering phenomenon of the light. When a laser light is focused over a liquid sample, it generates the vibration and rotation phenomenon in the sample. The scattering phenomenon of the light is generated as a result of the molecular vibration and oscillations. The degree of scattering for specific molecules solely depends on its concentrations levels. [3, 4, 7-9].

Limitations: The electrodes irritate the skin, which need to be in place for 60 minutes as required for Raman Spectroscopy to acquire a specific spectral signal, which some patients may lack patience to cope with. Readings were found to be sometimes inaccurate, mostly when the patient is sweating and electrodes were not able to detect rapid changes in blood glucose, as a result of its long starting time. Introduction of noise from the other glucose similar molecules exists and this affects the overall results. [7-10]. High cost equipments and Special detector are required [26].

Optical Coherence Tomography

Principle: It involves the use of super luminescent light source to generate a low coherence light. An interferometer with a reference arm and a sample arm, a moving in the reference arm, and a photodetector to measure the interferometric signal produced are required [10, 11]. Light backscattered from tissues is combined with light returned from the reference arm of the interferometer, and the photodetector detected the resulting interferometric signal [10]. The delay correlation between the backscattered light in the sample arm and the reflected light in the reference arm is measured. An increase in the glucose concentration level in the interstitial fluid causes an increase refractive index, which then creates a decrease in an unequal between sample and reference indices [10].

Limitations: It may be sensitive to the individual's motions; furthermore, due to the extreme change in skin temperatures, it produces incorrect results but error is negligible in minute skin temperature change [4, 11, 12].

Mid-Infrared (MIR) Spectroscopy

Principle: Mid-infrared (MIR) spectroscopy uses the same principles as infrared spectroscopy; as a result of this principle, it is the absorption measurement of MIR beam. It is based on light between 2500-25000 nm regions of the spectrum. Absorption differences when MIR light comes in contact with human tissues can be represented by certain modeling techniques in the spectral quantitative analysis. A partial least square algorithm is usually employed for multivariate calibration for these constituents [10, 13].

Limitations: Poor penetration is the major limitation [10, 13-15]. Insufficient accuracy is also a limitation [26].

Near Infrared Spectroscopy

Principles: The working principle is similar to that of MIR spectroscopy. Near infrared (NIR) spectroscopy is between the wavelength region of 730-2500 nm. [10]. When a beam of infrared light is focused over a tissue part, the light passes through certain phenomena known as absorption, reflection and scattering, etc [6, 12]. The information for the blood glucose concentrations could be obtained by using both the transmission and reflection property as the result of tissue interaction. The changes in the resultant wave property are detected by a suitable photo sensor for noninvasive blood glucose detection [6, 12].

Limitations: In spite of much promising work, researchers still cannot overcome important drawbacks, especially the scanning pressure that must be applied, physiological differences unrelated to blood glucose, the comparatively small fraction of glucose in the blood, weak correlation, hardware insensitivity and poor stability [10].

Optical Polarimetry

Principles: The basic principle of this Optical Polarimetry is that the linear polarization vector of the light will rotate when the light is passed through a substance and that the rotation measured is proportional to the concentration of the substance being monitored [16].Researchers are trying to apply optical Polarimetry as noninvasive glucose monitoring as the result of the high scattering coefficients. This produces complete depolarization when the beam strikes the skin. However, attention has been focused on the eye, which offers a clear optical medium with a reasonable path length in relation to blood glucose [17].

Limitations: Due to sensitive properties of the investigated tissue, it produces scattering by polarizes light. For this reason, there is difficulty in measurement, especially over the skin by polarization technology, because it shows a high scattering effect, in the stratum corneum. Also eye movement and motion artifacts are general sources of errors in this technique. In addition, the quality of this technique is poor, as several optically active compounds are present in human fluids having glucose, for examples albumin and cholesterol [10].

Fluorescence Technology

Principles: It utilizes fluorescence reagents to track the presence of glucose molecules in blood [18]. Human tissues produce fluorescence when irradiated by light at fixed frequencies. A laser beam of 308 nm when focused on glucose solution, the fluorescence occurrence is observed in the spectral ranges between 340 to 400 nm with extremely high peak close to 380 nm [3, 4].

Limitations: Ultraviolent light along with fluorescence, it causes a very strong tissue scattering properties. Optical skin properties and also causes variation in the fluorescence property of the human tissues so variation may not occur by glucose variation [3, 4].

Ocular Spectroscopy

Principles: This technique utilizes a special glucose sensitive hydro-gel with specially designed contact lenses. When the lens is illuminated by a light source, the reflected light changes its wavelength depending upon the binding occurrence related to tear glucose concentration. Spectrometer detects the light color change [3, 19, 20].

Limitations: Blood glucose concentrations vary in blood and tear over a marginal time period. Contact lens usage provides irritating experiences to some patients and furthermore it can lead to contact lens related severe eye infections [3, 4, 6, 7].

Challenges Facing Noninvasive Blood Glucose

In this review, the modern approved optical technologies; devices and limitations for noninvasive glucose monitoring are discussed. Unfortunately none of these technologies have produced a commercially available clinically reliable device; for this reason much work remains to be done in designing and developing a clinically reliable device for blood glucose monitoring. It is relatively simple to measure data and find correlation with blood glucose levels under the controlled conditions of research laboratories: the challenge is measuring these variables in normal environments. This requires the understanding of the physical and physiological factors that may affect blood glucose measurement. It is important to understand that noninvasive monitoring will never be actualized without good calibration approach. At this point, we are far away from reaching the aim of noninvasive blood glucose measurement, with many technical problems yet to be resolved. Good Calibrations approach and its stability for various conditions is an important factor to accomplish clinical desired aim of a successful noninvasive blood glucose measurement.

The fault-finding parameters are stated below:

i) To measure and record good quality of output signals with low interference (Signal to noise ratios)

ii) Vigorous calibration procedures for the experimental technique

iii) Filtering to prevent unwanted components or features from signal bearing blood glucose

iv) Ability to produce repeatable and consistent output results

v) The output results and experimental process must be less sensitive to both internal and external factors [3, 4, 21, 22].

vi) Problem solving approach is needed to achieve a successful blood glucose monitoring procedures [3, 4, 21, 22].

Mathematical Modeling for Blood Glucose Measurement

The Near infrared and Mid-infrared spectroscopy measure blood glucose through indirect techniques. The multivariate methods have been used to match up the input signal and output of the measured sample concentrations, which is determined by these major factors:

(a) Repeatable and good output as the result of good signal to noise ratios for accurate and stable measurements.

(b) The output of the spectroscopy techniques relies on the instrument condition, sample quality and reaction kinetics, filtering etc [2-4, 7, 14, 15].

Principle of Measurement

The Lambert-Beer law explains the intensity change on the light path by a specific wave number of the wavelength. Where the absorption is represented as A and the wave number is given as (v), The expression is represented as follows;

$$A(v) = -\log I(v) / Io(v) \quad (1)$$

Where (I_0) represents the intensity of incident light of the medium, (I) denotes the intensity of the light after it has passed through the sample at specific wave number (v) [23].

Proposed Methodology

In the recent years various optical analyses are currently the most promising and researched techniques of non-invasive in blood glucose analysis, with over 100 small Companies and Universities working on monitoring devices using these methods [27]. NIR and MIR spectroscopy based noninvasive techniques for determining the level of glucose concentration in the blood had been demonstrated by many group of researchers and excellent progress has been made in the past few years [3, 4]. For monitoring of blood glucose determination by noninvasive method, numerous optical techniques have emerged with promising results [3, 4].The near and mid infrared spectroscopy based method approaches have proven exceptionally in detecting blood glucose related signals for non invasive blood glucose predictions, as well as a very promising glucose monitoring technique [21, 22].

Figure 1: From the sketch of a proposed noninvasive blood monitoring device. The light source unit (Multi-Modal Light emitting diodes) provides light in the Infra red, visible light and near UV region. It is being focused on the finger tip. The output transmitted bio-signal is received by the Multi-Modal Photodetectors. Amplification is incorporated to magnify the feeble bio-signal. Filtering is introduced to prevent unwanted signals or features from the weak bio-signal. Alpha Numeric keypad uses to send message to the signal processing unit .The Signal Processing Unit helps in quantifying the blood glucose related information after suitable signal processing and conditioning the desired blood glucose level is displayed on the Liquid Crystal Display.

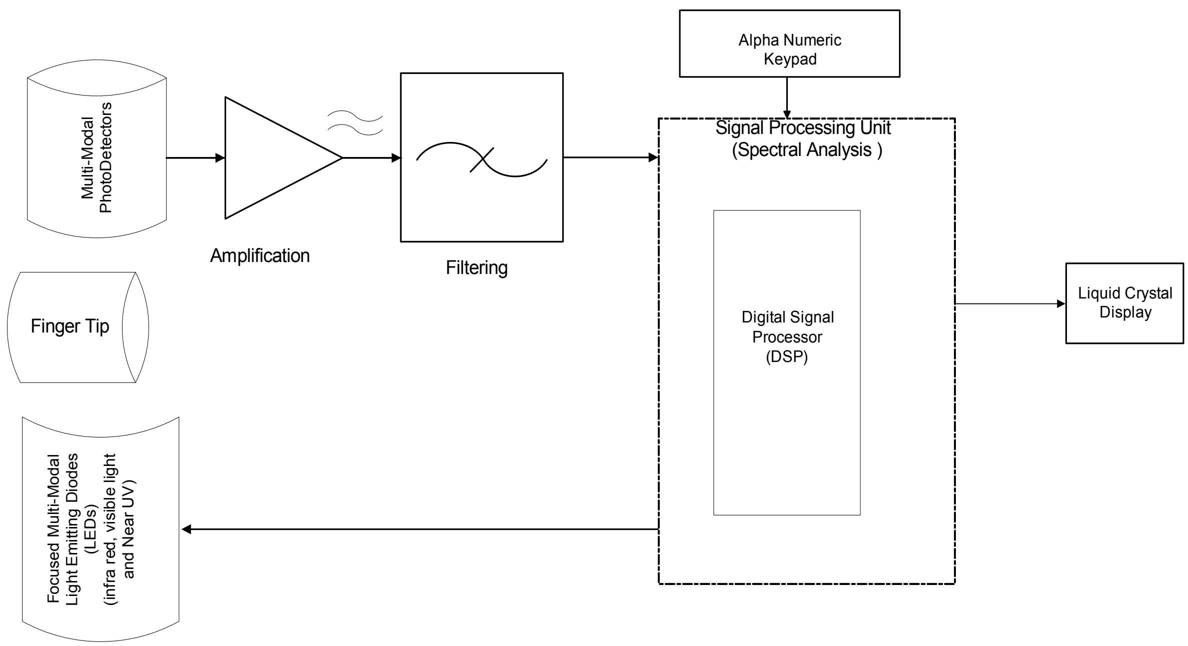

Fig1. *Block diagram of the proposed blood glucose measurement device*

Conclusion

Expensive and painful ways of monitoring blood glucose demand urgent development of new devices that could challenge and have better improvement in term of less-expensive, effective and painless method of monitoring blood glucose. An improvement in designing and development of noninvasive blood glucose technology will yield a novel edge for continuous blood glucose monitoring in order to detect accurate diabetes status in patients, promoting and increasing patient compliance, securing blood free measurement, and reduces work load over hospital workers, with easy diabetes control regimen. It can provide adequate check and control fluctuating higher or lower glucose level in the blood.

Recommendation

The authors would like to recommend the light source unit to provide light in the Infra red, visible light and near UV, multi-modal Photodetectors should be used and incorporation of suitable filtering and amplification circuits in the design and development of non-invasive method of blood glucose system, in order to achieve clinical output result.

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