Non Invasive Blood Glucose Measurement using NIR technique based on occlusion spectroscopy

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Abstract—Diabetes is considered to be one of the major health care epidemics of modern era. The determination of blood glucose concentration using the self-monitoring blood glucose devices involves the chemical analysis of blood samples taken by pricking the finger or extracting blood from forearm. The pain, discomfort and inconvenience in the current invasive method has led to the feasibility study of non-invasive measurement techniques.

In this paper, an optical method using NIR technique based on occlusion spectroscopy is used which shows that it can be possible to measure glucose concentration in blood non-invasively.

Keywords: IR transmitter, photodetector, occlusion, FFT analysis.

I. INTRODUCTION

Diabetes is a condition in the human body wherein the human body does not produce the quantity of insulin adequately required to maintain a normal circulating blood glucose. Insulin is a hormone that enables glucose to enter the body’s cells to be used for energy. As a result diabetics must regulate their own blood sugar levels through diet and insulin injections. Diabetes is considered to be one of the principle health care epidemics of the modern era. Diabetes can lead to very serious and severe complications including heart failure, blindness, gangrene and amputation.

The past two decades has attracted tremendous attention in the diagnosis and monitoring of diabetes by Non-invasive methods. One of the most important goals of diabetes industry is to achieve a reliable non-invasive method to monitor blood glucose levels. The methods existing today are very efficient and reliable providing accurate reading. But the necessity is to pierce the skin to draw drop of blood for carrying out analysis. No alternative method has succeeded in completely replacing the conventional blood glucose meters.

Non-invasive methods offer the main advantage of relief from pain and discomfort due to frequent finger pricks needed for the invasive analysis. NI determination of the glucose also promotes frequent testing, adequate control, reduce the complications and consequently reducing the health care costs.
Recently, the Israeli company OrSense [8] has claimed to have developed a new non-invasive technology for monitoring blood glucose levels for diabetes. The proprietary breakthrough technology known as Occlusion Spectroscopy uses a non-invasive optical measurement platform combined with a finger attached ring-shaped sensor. The pressure applied by the sensor temporarily occludes the blood flow in the finger, creating new blood dynamics which generate a unique, strong optical signal, yielding high signal to noise ratio that is wholly blood specific. Analysis of the signal provides sensitivity necessary to measure glucose, hemoglobin, oximetry (under severe low perfusion levels), pulse rate and other analyte concentrations.

II. NON INVASIVE METHODS

Non invasive blood glucose monitoring techniques can be grouped as subcutaneous, dermal, epidermal and combined, dermal and epidermal measurements [5]. Dermal and epidermal (limited to epidermal surface) glucose measurement techniques involve Near IR spectroscopy where absorption or emission data in the 0.7µm—2.5µm of spectrum are compared to known data for glucose. In Raman spectroscopy, laser light is used to induce emission from transition near the level excited. In photo acoustic spectroscopy, laser excitation of fluids is used to generate an acoustic response and a spectrum as laser is tuned. The scattering of light in scattering technique is used to indicate a change in the material being used.

Optical transmissions of tissue in vivo have been measured in red/near-infrared region [6]. Sudden blood flow cessation causes the light transmission rising. For certain wavelengths range this growth becomes non-monotonic. The correspondence between in vivo measurements and the theoretical simulations is reached if we attribute the transmission growth to the change of average size of scatterers. The most important blood parameters such as hemoglobin, glucose, oxygen saturation, etc., influence the transmission growth following over-systolic occlusion and, therefore, may be extracted from the detailed analysis of the time evolution of optical transmission. It forms a basis for new kind of non-invasive measurements, i.e., occlusion spectroscopy. The results of in vivo clinical trials are presented for glucose and hemoglobin.

There are three main issues in the non invasive (NI) glucose measurement namely specificity, compartmentalization of glucose values and calibration [3]. The methods used for NI determination of glucose can be classified as methods tracking molecular property of glucose and methods tracking effect of glucose on tissue and blood properties. The first category depends on tracking intrinsic property of glucose such as NIR absorption coefficient, MIR absorption coefficient, Raman shifts, NIR photo acoustic absorption. These methods assume ability to detect glucose in blood independent of other body components and also independent of body’s physiological state. The second set of methods depends on measuring effect of glucose on optical properties of tissues. The properties that are included are light scattering coefficient of tissue, refractive index of ISF and sound propagation in tissue.

Glucose in human body is distributed in different body components and can be found in blood, tissue ISF, eye vitreous fluid, tears and sweat. Several body sites were studied for NI determination of glucose e.g. finger, ear lobe, tongue, inner lip mucosa, the eye.

III. METHODOLOGY

Many methods have been proposed for the non invasive measurements but the main concern in non invasive technique is difficulty in achieving high accuracy of results as no blood is directly involved in the process. Use of optical fibers along with IR sensors based on Beer-Lambert law is proposed [1]. In the present work, non invasive technique based on occlusion spectroscopy using NIR and finger as the body site is tried and tested for analysis of glucose in blood. The subjects with diabetes Type II, low BP, high BP, low hemoglobin, and healthy condition were tested and analysis studied.

The experimental setup comprises of Infrared transmitter and receiver and finger as the body site. With proper positioning of the finger, over systolic pressure is applied to the finger to occlude the blood flow for a period of 30 seconds. The response of the optical signal thus obtained is studied by performing the FFT analysis using spectrum analyzer. The frequency spectrum is windowed for certain range using Hanning window. The difference in the peak frequencies is observed for two conditions i.e. Before occlusion and After occlusion. The interesting results obtained show frequency variation depending on the health condition of the subject. A considerable frequency variation was observed for diabetic patients, very low frequency change for BP patients and no variation in frequency for healthy patients. The table below gives a record of analysis and figures show the spectral response observed for some of the readings with reference to the data in the table.
### TABLE 1

<table>
<thead>
<tr>
<th>Sr.No.</th>
<th>Age</th>
<th>Sex</th>
<th>Condition</th>
<th>Frequency (in Hz) &amp; Span (in Hz) (Before occlusion)</th>
<th>Frequency (in Hz) &amp; Span (in Hz) (After occlusion)</th>
<th>Remark</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.*</td>
<td>26</td>
<td>Female</td>
<td>Healthy</td>
<td>1.465 (244.1)</td>
<td>1.465 (244.1)</td>
<td>No change in frequency</td>
</tr>
<tr>
<td>2.*</td>
<td>26</td>
<td>Female</td>
<td>Healthy</td>
<td>20.98 (976.6)</td>
<td>20.98 (9.766)</td>
<td>No change in frequency</td>
</tr>
<tr>
<td>3.</td>
<td>50</td>
<td>Male</td>
<td>Low BP</td>
<td>1.758 (48.83)</td>
<td>488.3m (48.83)</td>
<td>Difference of approx. 1.2 Hz</td>
</tr>
<tr>
<td>4.</td>
<td>33</td>
<td>Male</td>
<td>Diabetic (Diet controlled)</td>
<td>4.960 (97.66)</td>
<td>11.92 (488.3)</td>
<td>Observed a change of 7 Hz</td>
</tr>
<tr>
<td>5.*</td>
<td>33</td>
<td>Female</td>
<td>Low BP</td>
<td>2.930 (244.1)</td>
<td>4.053 (244.1)</td>
<td>Difference of approx. 1.1 Hz</td>
</tr>
<tr>
<td>6.*</td>
<td>33</td>
<td>Male</td>
<td>Diabetic</td>
<td>5.898 (488.3)</td>
<td>116.2 (488.3)</td>
<td>Frequency variation of 110.541 Hz</td>
</tr>
<tr>
<td>7.</td>
<td>46</td>
<td>Female</td>
<td>High BP</td>
<td>3.145 (244.1)</td>
<td>976.6m (244.1)</td>
<td>A change in frequency of approx. 3.2 Hz</td>
</tr>
<tr>
<td>8.*</td>
<td>46</td>
<td>Female</td>
<td>High BP</td>
<td>2.623 (244.1)</td>
<td>3.099 (244.1)</td>
<td>A change of 0.47 Hz observed</td>
</tr>
<tr>
<td>9.</td>
<td>33</td>
<td>Male</td>
<td>Diabetic</td>
<td>2.146 (244.1)</td>
<td>85.83 (244.1)</td>
<td>A large variation in frequency of approx. 83 Hz observed</td>
</tr>
<tr>
<td>10.</td>
<td>51</td>
<td>Male</td>
<td>Low BP</td>
<td>3.416 (244)</td>
<td>1.465 (244.1)</td>
<td>Frequency variation of 1.95 Hz</td>
</tr>
</tbody>
</table>

### IV. RESULTS

The following figures are shown for the cases marked * in the above table i.e. Sr.No.1,2,5,6 and 8.

### V. DISCUSSION

As can be observed from the results:
- Fig.1 and Fig.2 the frequency variation is zero and remains constant at a value of 1.465 Hz.
- Fig.3 and Fig.4 also shows no variation in frequency as both these cases are for healthy subjects.
- Fig. 5 and fig.6 shows the response of diabetic subject with blood sugar of 222mg/dl.
- Fig. 7 and Fig.8 shows the result of the subject with high BP with frequency variation of about 0.47 Hz.
- Fig. 9 and Fig. 10 shows the response for the subject with low BP with a variation in frequency of 1.12 Hz.
Healthy subject

Figure 1  Before occlusion

Healthy subject

Figure 2  After occlusion
Figure 3  Before occlusion

Figure 4  After occlusion

Diabetic patient
Figure 5  
Before occlusion

Figure 6  
After occlusion
High BP patient

Figure 7

Before occlusion

Low BP patient

Figure 8

After occlusion
CONCLUSION

For the non invasive blood glucose measurement the circuit is designed using infrared sensors and experimentation based on occlusion spectroscopy yielded interesting results. The FFT analysis was performed with all types of patients. The spectral response results are related to the subject’s health condition. The
experimentation demonstrated the design issue and this information can definitely aid in identification of glucose concentration though it needs further analysis.

REFERENCES