Early Detection of Chronicity Foot Lesion in Diabetic Neuropathy Patients

Mrs. S Saranya¹, Mrs. N Banupriya², Ms. S Sivaharni³, Ms. E Suvalakshmi⁴ and Ms. B Suganthi⁵

¹,² Assistant Professor, Department of Electronics and Communication Engineering, Sri Ramakrishna Engineering College, Coimbatore - 641022, Tamil Nadu, India.
³,⁴,⁵ Student, Department of Electronics and Communication Engineering, Sri Ramakrishna Engineering College, Coimbatore - 641022, Tamil Nadu, India.

Abstract This paper describes about the early detection of chronicity foot lesion in diabetic patients by monitoring their foot pressure. Patients with diabetic for long term and poor glycemic control are often leads to peripheral neurovascular disorder. This neurovascular disorder is caused due to Diabetes Triopathy (inadequate levels of growth factors & presence of biofilm). This neurovascular complication results in foot ulceration. 40% to 50% of diabetic patients are affected by foot ulceration. These ulceration leads to lower extremity exclusion even in the absence of critical branch ischemia. So, early detection and prevention of foot ulcer is needed. In this paper, hardware is setup to monitor the foot pressure in diabetic patients continuously with the help of flexi force sensor. For effective screening of foot ulceration, a graphical program environment LABVIEW is used. In this work, foot ulcer is detected earlier. So that it can be prevented earlier. Normalized PeakPressure (KPa) values are listed based on collected performa and had classified the diabetic patients and normal patients.

Keywords: Diabetic foot ulceration, neurovascular disorder, Ischemia, LabVIEW.

1. Introduction

The physical work like standing, walking and running are supported by our foot. Our foot is the foundation /basement of our whole body, it can adapt to uneven surface, it act as a shock absorber for our body. Loss of any one of these function will result in defect in the feet. It is often noticed in diabetic patients and it indicates that there is a risk of developing foot ulceration[5]. Patients with diabetic for long term and poor glycemic control are often leads to peripheral neurovascular disorder. This neurovascular disorder is caused due to inadequate levels of growth factors and presence of biofilm[3].

In India, diabetics mellitus is the most common disease. In addition to diabetics mellitus there is another disease called diabetics insipidus. Diabetics insipidus occurs when our body can’t properly balance the body’s fluid levels where, Diabetics mellitus is a chronic disorder of carbohydrate, protein, and fat metabolism resulting from insulin deficiency or abnormality in the use of insulin[9]. The normal range of glucose level is 70 to 130 mg/dl. There are two main causes for diabetic mellitus: Our body fails to produce insulin; cells fail to use insulin. Diabetic mellitus patients should maintain their sugar level regularly or otherwise it leads to various problems like poor blood flow, poor sensation, and tissue damage and neuropathy or neurovascular disorder[4]. Diabetic mellitus with neurovascular disorder leads to foot ulceration. Foot ulceration is the major complication of diabetic mellitus. Diabetic foot ulcer (DFU) is mainly caused by neuropathy, ischemia, and infection lead to tissue breakdown or ulceration resulting in amputation. Foot ulceration often leads to amputation of the affected limb. If the numbness is present the foot pressure will be decreased.[2].

The initial steps for preventing diabetic foot ulcers are monitoring foot pressure daily using diabetic footwear and educating patients to take proper care of their feet. If there was any small variation in
their foot pressure it must be monitored and the patients should take their medications. It is the effective method for reducing the rate of foot ulceration in diabetic patients. With the help of current technology, these devices can be placed as an insole in our normal footwear. Since, the diabetic foot wear is cost effective the patients can use it and can prevent them from foot ulcer.

Datasets of 50 diabetic patients with and without foot ulceration were analyzed. The normalized foot pressure is measured between 400 to 750 kpa (kilo Pascal)[5]. The patients with pressure below 400 kpa are at the risk of developing diabetic foot and pressures below 280kpa are at higher risk of developing diabetic foot. Since, diabetics are one of the form of the genetic disease which comes in hereditary DNA. Overweight/Obesity is an another reason for diabetic foot ulceration. For those patients we have to check Body mass index (BMI)[2]. If the patients BMI ranges from 25 to 29.9(kg/m2) can be considered as that they are in the early stage of foot ulcer.

1.1 Classification and Management control of Diabetic foot

The stages and simple management plan [8] for each stages are briefly described:

### Table 1: Stages and Management control of Diabetic Foot

| Stages | Lesion                  | Management control       |
|--------|-------------------------|--------------------------|
| Stage 0| No open lesions         | Wound control            |
| Stage 1| Superficial ulcer       | Microbiological control  |
| Stage 2| Deep ulcer              | Mechanical control       |
| Stage 3| Deep ulcer with abscess | Vascular control         |
| Stage 4| Local gangrene          | Metabolic control        |
| Stage 5| Gangrene of entire foot | Educational control      |

2. Diagonsistic Process

2.1 Glycoselated Hemoglobin (HbA1c)

HbA1c is a test to measure the amount of glycated hemoglobin in our red blood cells and it is formed by the combination of blood sugar and hemoglobin. The normal level ranges from 5.4-6.8mg/dl[6].

2.2 Blood Pressure

This is one of the tests to diagnose foot ulcer. Blood pressure is measured using sphygmomanometer[6]. The variation in the systolic pressure of right and left leg indicates that the foot is at risk of developing foot ulcer.

2.3 Doppler Test

This is another method to test foot ulcer. Doppler test is done to check the blood flow in the foot region[6]. In this test a gel is applied in foot region and a device is made to move on the foot area. Then the blood flow is recorded by sound.
3. Software used

3.1 LabVIEW

National instruments is one to introduce Lab view which stands for Laboratory Virtual Instrument Engineering Workbench. LabVIEW is easy tool to create program since it uses icons instead of line of text. The main reason to use LabVIEW is for graphical representation of the output. The application of LabVIEW includes data acquisition and data analysis. In LabVIEW there is a tool called VISA (Virtual instrument software architecture), which was implemented by several Test and Measurements companies such as National Instruments. VISA is widely used as I/O API. Actually, VISA transmits/receives data from/to UART[10].

4. Hardware used

There are different types of sensors like strain gauge, piezoelectric force sensor, optical force sensor, flexi force sensor are available to measure pressure. Here, Flexi force sensor is used for foot pressure measurement. Force sensor consists of force gauge which is used to detect small force during a pull or push. Flexi force sensor has a 0.5” diameter, sensing area. The resistance of the Flexi force sensor will vary depending on pressure applied to the sensing area. This FSR can sense the applied force anywhere in the range of 100kg - 10kg[1]. PIC16F877A belongs to the family of microcontroller which is manufactured microchip technology. There are 35 instructions, 35 input/output pins, 8K ROM FLASH memory, 256 bytes EEPROM data memory, 368 bytes RAM memory, 10 bit analog to digital converter are available in PIC16F877A[5]. The light modulating properties of liquid crystals are used by LCD (Liquid Crystal Display) also called as flat panel display which do not emit the light directly. Words, digits and 7-segment display can be displayed using LCD. LCD is mainly used for the applications such as signage, computer monitors, televisions, aircraft cockpit displays. A computer hardware device used for asynchronous serial communication is named as UART (Universal Asynchronous Receiver and Transmitter). The transmission speed of UART is 921.6 kbits/second. UART receives/sends data to microprocessor/microcontroller through data bus. UART is used as an communication link between two devices. UART is mainly used for serial communication.

![Figure 1: Hardware Setup](image)

5. Proposed Methodology

Early detection of the foot ulceration in diabetic patients can be monitored by their foot pressure. Overweight/Obesity is the main risk factor for diabetic foot lesion[2]. The BMI (Body Mass Index)
and foot pressure value directly dependent on each other. So we have to calculate the BMI value for the patients. Foot ulceration often leads to amputation of the affected part. So, early detection and prevention of foot ulcer is needed. A designed circuit is placed in foot wear of the patient which continuously measures foot pressure of the patient with the help of flexi force sensor. The output will be in terms of kilopascal (kpa). Pascal (pa) and Kilopascal (kpa) are the units of pressure. If the output is in terms of Kg/cm² then it should be converted to Kilopascal (kpa). The conversion is shown below. The effective screening of foot pressure, a graphical programmable environment is done in the LabVIEW. The hardware and software was interfaced using the UART (Universal Asynchronous Receiver and Transmitter).

![Block diagram](image)

**Figure 2**: Block diagram

5V to 12V power supply is used to give supply to the circuit. Insole is a place where two sensors are placed. PIC16F877A is used as an analog to digital converter. LCD is used to display the digital output from the PIC16F877A. UART is used to interface PIC16F877A with LabVIEW. It transmits the data serially to LabVIEW. LabVIEW receives the data from the UART and the graph was plotted.

![Schematic diagram](image)

**Figure 3**: Schematic diagram

5V to 12V supply is used to give supply to the circuit. Two force sensors used to measure the foot pressure. One sensor is placed in foot (F1) and another one is placed in toe (F0). The two sensors which is placed in insole senses the pressure given by the patients. The output of the sensor will be an
analog signal. PIC16F877A is used as an analog to digital converter. PIC16F877A has 5 ports (port A, B, C, D, E). Port A and E acts as an analog to digital converter. The two sensors are connected to the ADC pin RA0 and RA2. The analog signal from the sensor is fed to PIC16F877A. It converts the analog signal to digital signal. A 16X2 LCD is used to display the output values and it is connected with PIC16F877A. The digital output from the PIC16F877A will be displayed on the LCD display. UART is connected to both PIC16F877A and PC. UART receives data from the PIC16F877A and transmits the data to PC (LABVIEW) serially. The data from the PIC is fed to LabVIEW using UART. LabVIEW collects and Analyze the data and the graph was plotted. There is a control knob in front panel to indicate the doctors whether the patients is having normal or abnormal foot.

6. Results and Discussions

The age, weight, height, BMI, sugar level, foot pressure of diabetic patients are given below:

| S.no | Sample | Age (yrs) | Weight (kg) | Height (cm) | BMI (kg/cm²) | Sugar level (pre meals) (mmol/L) | Sugar level (post meals) (mmol/L) | Foot Pressure (kpa) |
|------|--------|-----------|-------------|-------------|--------------|----------------------------------|-----------------------------------|-------------------|
| 1.   | A      | 58        | 80          | 150         | 35.6         | 126                              | 153                               | 595               |
| 2.   | B      | 59        | 73          | 156         | 30           | 80                               | 176                               | 634               |
| 3.   | C      | 64        | 80          | 162         | 30.5         | 158                              | 209                               | 248               |
| 4.   | D      | 47        | 78          | 157         | 31.6         | 98                               | 185                               | 627               |
| 5.   | E      | 50        | 78          | 158         | 31.2         | 147                              | 234                               | 252               |
| 6.   | F      | 53        | 76          | 168         | 26.9         | 152                              | 195                               | 465               |

From the above table we infer that the samples A, B, D, have normal blood sugar level and the foot pressure is also above 400kpa. The samples C, E, F have high blood sugar level 158 mmol/L, 147 mmol/L and 152 mmol/L respectively where C and E does not have a proper foot care which results in abnormal foot pressure value 242 kpa and 252 Kpa resulting in foot numbness. If this is untreated it may result in foot ulcer. Even though the sample F have high blood sugar the foot pressure value is 465kpa which shows that the sample is very precautionary in foot care problems and follows proper medications regularly.

➢ **Formula to calculate BMI:**

\[ \text{BMI} = \frac{\text{Weight in kg}}{\text{Height in cm}^2} \times 10000 \]  

Example:

Weight in kg = 80  
Height in cm = 150  
BMI = 35.6 (kg/cm²)

➢ **Conversion of Kg/cm² to Kpa:**

\[ \text{Kpa value} = \text{Kg/cm}^2 \times 98.0665 \]  

Example:

If the flexi force sensor output is 60Kg/cm² then the pressure in Kpa is,  
Kpa value = 60 Kg/cm² X 98.0665 = 588Kpa.
Figure 4a: Foot Pressure value of normal sample through LabVIEW Simulation

Figure 4b: Foot Pressure value of abnormal sample through LabVIEW Simulation
The above figure 4a and 4b represents the front panel of LABVIEW at two different scenarios. The graphical representation consists of time and Foot pressure in X and Y axis respectively. The figure 4a shows the pressure value when a Diabetic Patient with Proper Foot care uses the hardware where figure 4b showsthe pressure value when a Diabetic Patient with no Proper medication and meager foot care uses the hardware. Based on the above calculation and numbness relation with pressure, the upper and lower limit of pressure values are fixed as 750kpa and 400kpa respectively for normal patients. If the pressure given by the patient is below 400kpa then it will indicate as abnormal foot.

7. Conclusion

In this paper, foot pressure is measured to detect the foot ulcer earlier. The foot pressure for both normal and diabetic subjects were analyzed. The results indicates that the subjects with the foot pressure range between 400kpa to 750kpa are having normal foot and the subjects with the range below 400kpa are having abnormal foot. Monitoring and detecting of foot ulcer earlier reduces foot amputation problems.

In future, the footwear circuit can also be designed for normal person. For example, Now a days girls are used to wear heels. So, that many problems will arise like foot pain, unnatural position which inhibits blood circulation to the feet. So, they are also in need of monitoring their foot pressure.

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