Nat. Volatiles & Essent. Oils, 2021; 8(5): 3468 - 3476

NVEO
Natural Volatiles & Essential Oils

Blood Leak Detection during Hemodialysis

[1]Kavya S, [2]Anusuya K V, [3]Praveena G

[1]*Department of Electronics andCommunication Engineering*
*PSG College of Technology*Coimbatore, TN, India 18l123@psgtech.ac.in

[2]Associate Professor *Department of ECE*
*PSG College of Technology*Coimbatore, TN, India kva.ece@psgtech.ac.in

[3]*Department of Electronics andCommunication Engineering*
*PSG College of Technology*Coimbatore, TN, India 18l137@psgtech.ac.in

Abstract
Operations in the medical field require a high degree of accuracy and sensitivity else the result could be fatal. Hemodialysis is the process of filtering blood artificially using adialyzer. It is a process with a high success rate. However, the dangerous two possibilitiesof blood leakage are the demerit of this system. When such operations are monitored using technology, the danger can be avoided. Theblood leak detection system can warn the concerned persons regarding the leak and hence the patient would get immediate attention. Blood leakage due to Venous Needle Dislodgement (VND) and dialysate membrane rupture are detected usingimage processing technique and optical sensor module respectively, to warnthe person regarding the leak. The main unit of the system is a Raspberry Pi 3 B+ board to which the input peripherals like Pi Camera, Analog to Digital Converter from an IR LED Photodiode circuit is interfaced. Periodically, at every time interval,the conditions are recorded and monitored for any change that detects blood leaks. For every detection, the module warns the concerned persons.

Keywords- *Analog to Digital Conversion, Image Processing, IR Led, OpenCV, Python, Photodiode Pair, Raspberry Pi.*

I. INTRODUCTION

In recent years, kidney renal failure is found to be a majordisease in developed and developing countries. Among various therapy methods, hemodialysis is accepted as the besttreatment offered. In this method, impure blood is taken fromthe veins using a venous needle catheter and is made to pass into a dialyzer. The dialyzer has a semi-permeable membranein it separating a dialysate fluid and incoming blood. The impure salt, ions from the blood pass into the other chamber through the dialysate membrane. However, this highly successful therapy may fall short in two cases:

- *Venous Needle Dislodgement (VND)* - The needle inserted on the arm gets dislodged and hence the blood leaksout.
- *Rupture in the dialysate membrane* – It results in leakage of blood into the dialysate fluid chamber which usuallyconsists of clear fluid.

In this paper, the blood leakage in the gauze is detected using the image processing technique for the

blood leakage due to Venous NeedleDislodgement. An optical sensor module is implemented to detect even the smallest presence of blood inthe dialysate tube due to membrane rupture. The method used here is to process the image captured of the gauze, and checkfor a leak. Simultaneously the tube is also checked for bloodin it.

When any one of the cases is true, immediately a warningis sent to garner immediate attention for the patient. Hence, using a non-invasive method, blood leakage is detected inashort time.

II. LITERATURE SURVEY

In paper [1], the method of image processing using OpenCV to detect blood leaks from the arteriovenous fistula in the case of venous needle dislodgement is proposed. Red sensing algorithm is applied to detect the blood leak in the tube. In paper [2], a photocell array patch is used to detect the smallest quantities of blood leakage in the tube and a warningis sent using a Bluetooth module. In paper [3], a combinationof absorbent material and photo-interrupter is used. A small amount of blood gets absorbed completely by the material and the light changes are detected by the photo-interrupter. Paper [4] describes a device that uses a patch to adsorb blood and itis specifically used as a blood leak detector for hemodialysis. But it is an intrusive approach to detect blood and it may lead to irritation in the patched area.

Further, paper [2] proposes a system that is not very cost-effective compared to the system described in paper [3] because of the requirement of an array of photocells. Both [2] and [3] implement the alarmingmodule of the system using Bluetooth, a short-rangecommunication protocol. The system may fail in scenarios, where the helpers are far from the patient. Also, an arrangement kept closer to the arteriovenous fistula can causecomplications.

III. PROPOSED METHODOLOGY

The overall block diagram of the proposed system is shown in Fig. 1 and it overcomes the disadvantages mentioned in II, by using a non-invasive and sensitive method of detecting blood leak on gauze and dialysate tubes using image processing and optical sensing respectively. The system integrates an optical sensor moduleand an image processing module. To detect blood inthe dialysate tube, a pair of IR LED and Photodiode circuits areused. When the tube is filled with blood rather than a clear dialysate fluid due to membrane rupture, the voltage at the receiver side reduces and is used to detect the blood leak. Once the voltage drop is encountered, a warning text message is sent. *Venous Needle Dislodgement*

The presence of blood on the protective gauze of the patient confirms the blood leak due to needle dislodgement. This is detected using image processing. The images captured by Pi Camera are processed to detect red coloration in them using OpenCV. When the range of red matches any of the pixels of the image captured, it is understood as a blood leak. And the warning is sent as a text message using Nexmo and MQTT.

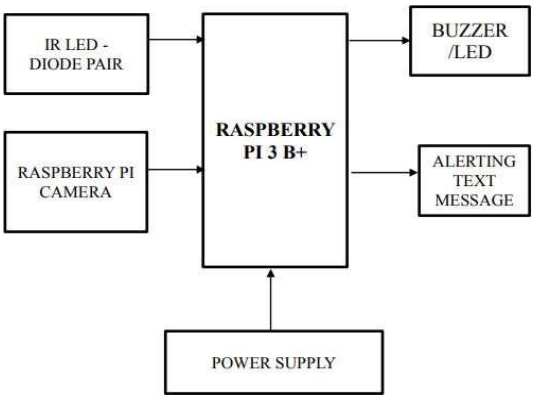

Fig. 1. Block Diagram of the Proposed System

A. Rupture in the dialysate membrane

The optical sensor consists of two parts, the emitter circuit, and the receiver circuit. The emitter is an IR LED andthe detector is an IR photodiode. Both IR LED (TSFF5210)and Photodiode (BPV10NF) are of dimension 5mm and tuned to the same IR wavelength. The photodiode is tuned to the same wavelength with a blocking filter matched with 870 to 890nm.The IR LED emits IR radiation, reception. The intensity of the received signal from the photodiode dictates the output of the sensor. The IR photodiode is sensitive to the IR lightemitted from an IR LED. The photodiode's resistance and output voltage change according to the proportion of the IR light received.This is the underlying working principle of the opticalsensor. The output voltage is sufficiently amplified by an amplifier as in Fig.2 and then given to the Raspberry Pi board via a high precision analog to digital converter to detect smaller changes in the output voltage due to change in fluid in the dialysate tube.

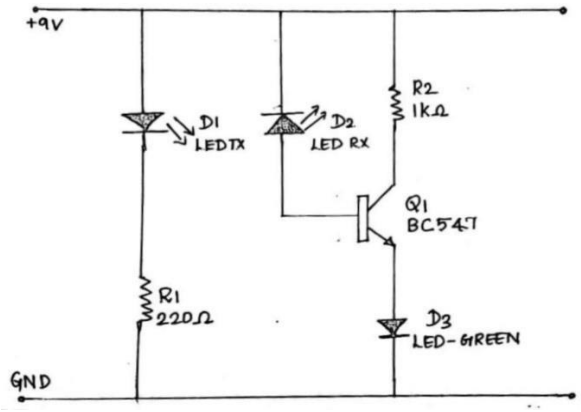

Fig. 2. Optical Sensing Circuit

IV.IMPLEMENTATION

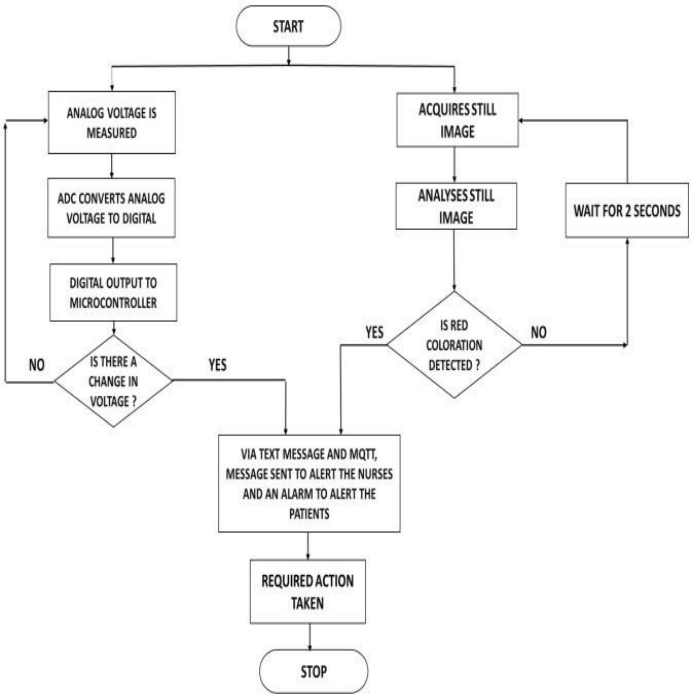

Fig. 3. Workflow of the Proposed System

The workflow of the proposed system shown in Fig. 3is for the detection of blood leaks during hemodialysis in twopossible cases.

A. Venous Needle Dislodgement

Whenever there is a rupture in the dialysate membrane or there is needle dislodgement in the arm of the patient, a blood leak can occur. Image of the gauze which is usually white is taken every 2 seconds with the Raspberry PiCamera and analyzed for the presence of blood by processing every pixel in the image. Each pixel in the image is checkedfor red coloration using OpenCV. If any pixel matches with the given range of red color, the buzzer is turned on and a corresponding message is sent through MQTT host and message API, Nexmo thereby detecting removal of the needle from the patient's arm.

B. Rupture in the dialysate membrane

The dialysate tube continuously flushes out the impureclear fluid. If there is a membrane rupture, the blood also flows in the tube. So to detect blood in the tube, an optical sensingcircuit as in Fig. 2 is implemented. The tube is placed in between the IR-LED Photodiode pair and is continuously checked for an abnormal reading. The IR- LED emits light and is captured by the Photodiode. The voltage is amplified using transistor BC547 and a LED is connected tothe emitter of the transistor to continuously measure the voltage. The analog voltage measured across the LED is converted to a digital value using Analog to Digital Converter (ADS 1115) and given as input simultaneously

to the microcontroller. In the presence of red blood in the tube, the intensity of light absorbed by the photodiode falls.As a result, the voltage also reduces. If the voltage falls below a particular value, a buzzer is turned on and the warningmessage is given. Thus a rupture is detected in the dialysate membrane that causes blood to flow into the tube along with the dialysate liquid.

ADC ADS1115RESULT ANALYSIS

A. *Venous Needle Dislodgement*

Raspberry Pi camera is focused on the protective white gauze. In the absence of blood, the OpenCV window doesn't show the presence of red color as shown in Fig. 7. When theneedle dislodges and blood trace appears on the gauze, OpenCV shows the presence of red color thereby indicating blood leakage and Python shell displays a blood leak detected message as in Fig. 8. The image is captured once every 2 seconds and even small traces of blood on the gauze is detected. A warning text message which is sent to the client mobile number using message API, Nexmo is shown in Fig.9.

LED-DIODE PAIR

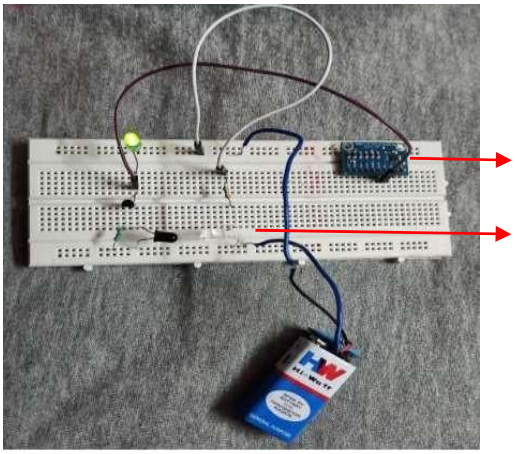

Fig. 4. IR LED-Diode Sensing Circuit

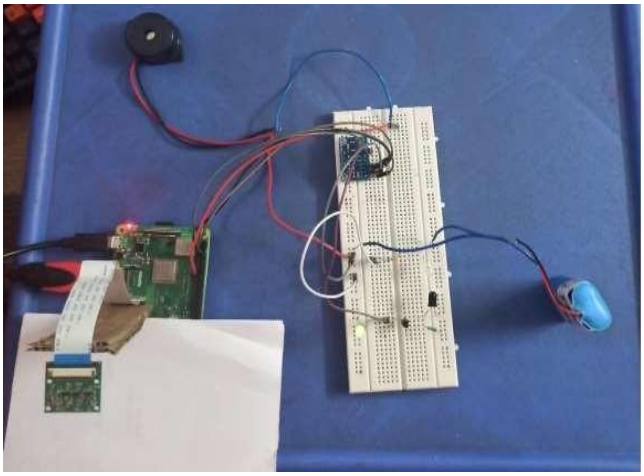

Fig. 5. Proposed System Circuit

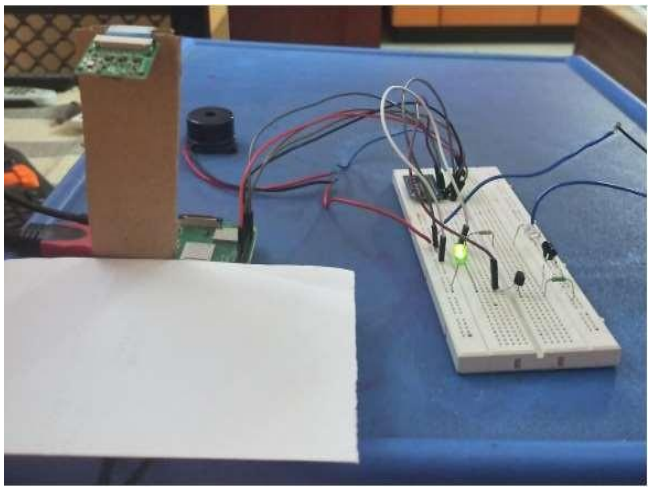

Fig. 6. Final Implementation of the Proposed System - Side View

Fig. 7. OpenCV window displaying the captured image of the gauze

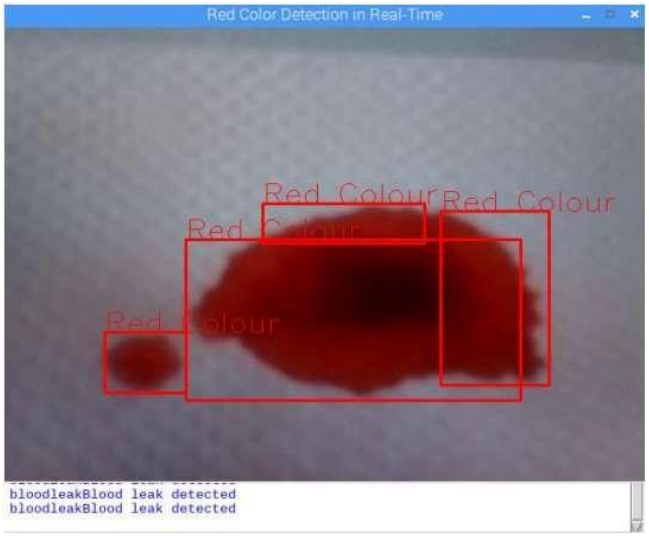

Fig. 8. OpenCV window detecting the presence of a red color (blood leak)and the message is displayed in the Python shell

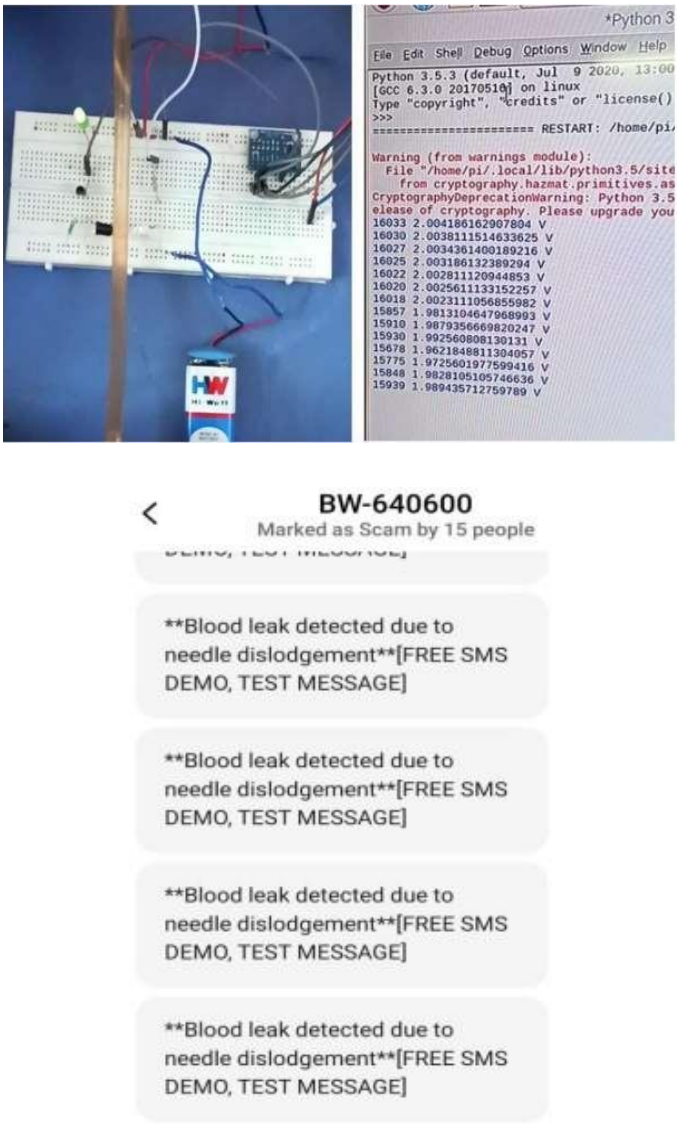

Fig. 9. SMS received by the Registered Mobile Number – Venous Needle Dislodgement

B. Rupture in the dialysate membrane

The voltage readings at the LED are converted todigital values through ADC and transmitted to the microcontroller using the I2C interface. The readings are monitored for values below the threshold corresponding to blood leakage. Table. 1 shows the voltage readings observed during each scenario in hemodialysis. Fig10 shows the normal scenario existing during hemodialysis. The voltage obtained in the presence of blood in the tube, that is, 1.95 Volts (threshold voltage), the buzzer is turned on. This is shown in Fig. 11. A warning text message is also sentto the client mobile number using message API as shown inFig.12 indicating dialysate membrane rupture.

MQTT host is created using test.mosquitto.org which gives appropriate warnings (for the two cases of bloodleakage) under 2 topics that are subscribed by the subscriberand published by Raspberry Pi. The message that is receivedby the client is shown in Fig. 13.

CASE NO	BETWEEN LED AND PHOTODIODE	VOLTAGE (V)
1	No obstacle	1.99≤V<2.01
2	Tube with clear fluid	1.96<V<1.99
3	Tube with blood	<1.95

Table.1. Voltage ranges for three cases in optical sensing

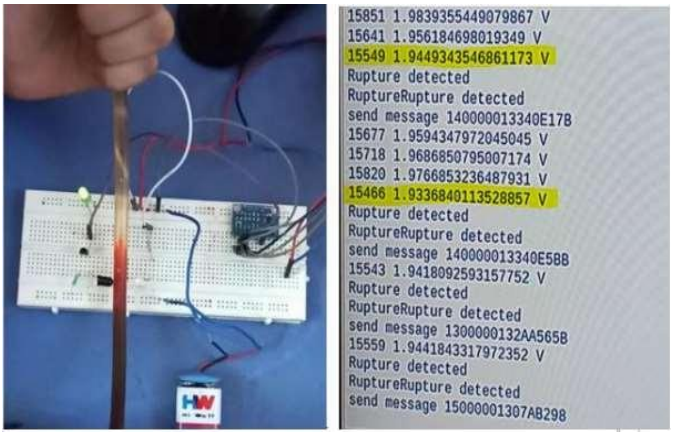

Fig. 10. Absence of blood in the tube (Clear fluid)

Fig. 11. Presence of blood in the tube and the drop in voltage below1.95V indicating rupture in the membrane

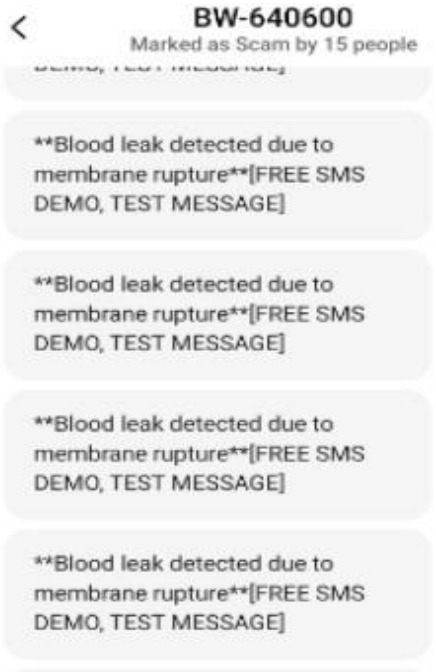

Fig. 12. SMS received by the Registered Mobile Number – DialysisMembrane Rupture

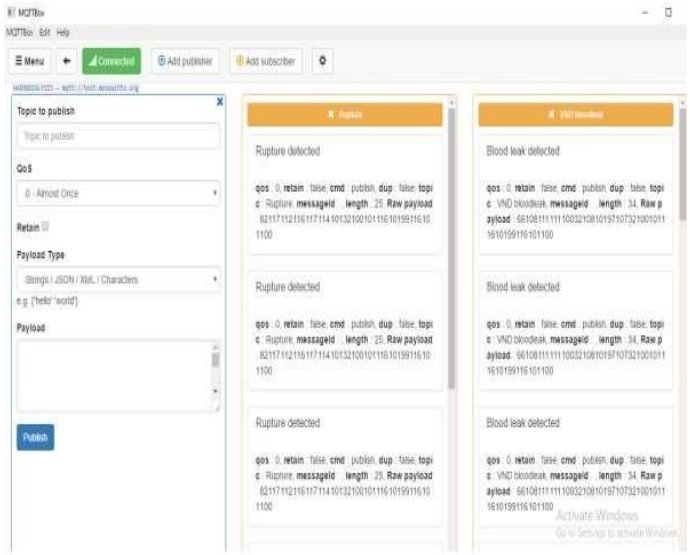

Fig. 13. Warning messages displayed under 2 topics in the MQTT host

V. CONCLUSION

The problems addressed are the two cases of blood leak during hemodialysis: Venous Needle Dislodgement and Dialysate membrane Rupture - Blood in dialysate tube. Image processing and optical sensing modules are implemented to immediately identify these problems and give appropriate warnings thereby avoiding fatal damage. Thenon-invasive approach also offers lesser chances of infection and no discomfort for the patients. It doesn't require extra patches or absorbent materials to detect blood leakage. This module can be applied in other cases of medical science where there is a possibility of blood leaks. Blood leak detection over gauze can also be employed in other treatments where there is a need to remove blood from the body using a catheter that mayget dislodged. The optical sensor module can further be appliedto detect backflow of blood from a syringe by monitoring the tube which should have a clear fluid like glucose.

REFERENCES

1. Kempegowda, Balakrishna, "Blood Leakage analysis duringHaemodialysis treatment using Image processing" in InternationalJournal of Research in Electronics and Computer Engineering (IJRECE), vol.7,2019
2. Nandini Rao G, Meenakshi M, V K Agrawal, 2020, "A Studyof Optical Sensor based Methods used for Blood Leak Detection During Hemodialysis", INTERNATIONAL JOURNAL OF ENGINEERING RESEARCH & TECHNOLOGY (IJERT) Volume 09, Issue 06 (June 2020)
3. H. Chuang, C. Shih, C. Chou, J. Huang, and C. Wu, "The Development of a Blood Leakage Monitoring System for the Applications in Hemodialysis Therapy," in *IEEE SensorsJournal*, vol. 15, no. 3, pp. 1515-1522, March 2015.
4. http://www.redsensemedical.com/, accessed Feb.13.2014
5. Optical Sensing: http://www.instructables.com/intro-to-ir-circuits/
6. Datasheet: http://www.alldatasheet.com/
7. Warning text messages: https: //maker.pro/ raspberrypi/ projects
8. /how-to-send-text-messages-from-a-raspberry-pi