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An Easy and Economical Option for Dialysis Patients to Solve Their PD Problems: Automated Peritoneal Dialysis

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Abstract— Human Excretory system plays an important role in maintaining the fluids in human body and kidneys are the way to perform this vital role. Extra care must be taken for kidneys to function properly and in case if kidney failure, artificial filtration (Dialysis) must be opted as an option immediately. Dialysis is performed in two ways: (a) Hemodialysis, (b) Peritoneal Dialysis. APD is one of the methods of Peritoneal Dialysis which has become very popular among ESRD patients in recent years as an alternative to Hemodialysis. In this understanding, a low cost machine for APD which will be easily available & affordable to common man is projected.

Thus, the paper is aimed to draw a sense of awareness in people regarding the option of APD for a much regular & healthier lifestyle. The proposed method is designed after considering the pros & cons of the available systems in market.

Keywords— Kidneys; Peritoneal Dialysis; Automated Peritoneal Dialysis (APD); End Stage Renal Disease (ESRD);

I. INTRODUCTION

Automated Peritoneal Dialysis is the most broadly used dialysis treatments in the hospitals for ESRD patients. It uses an automated machine which is programmed efficiently perform artificial filtration. The dialysate solution is filled in the abdominal cavity and the waste is diffused from the abdominal cavity with the common working of pumps, motors and other peripherals controlled by the microcontroller.

The following section explains the role of kidneys, their functions, the acute and chronic causes of kidney failure, the treatment solution: Dialysis and its types.

Kidney and its Function

Kidneys: lie on the each side of the spinal cord near middle of the back below the rib cage. Kidneys are major part of the excretory system. They perform the functions of removing extra water, salts and wastes of protein absorption from the blood while providing nutrients back to the blood. They perform this function with the help of filtering sections called 'nephrons'. These nephrons work in a two-way process: (a) the glomerulus lets the fluid & waste products pass through it; avoiding blood cells & other large molecules from passing, (b) the filtered fluid then passes through 'tubule', which resends the needed nutrients back to the bloodstream, thus eliminating the waste (urine).

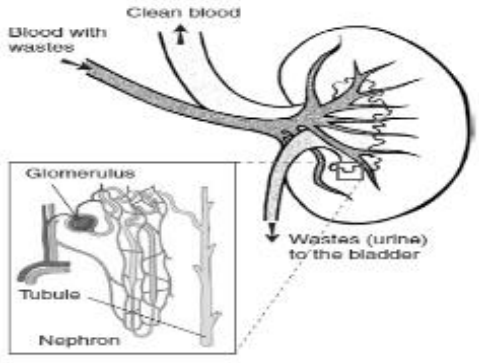

Figure (1) Kidney anatomy with its filtering sections

Most kidney diseases attack the nephron, thus hampering their filtering capacity. The nephrons can be injured quickly, often as a result of an injury or due to poisoning. It is only after years and when not taken proper care, the damage becomes fatal and hard to cure. The common and mostly observed causes of kidney failure are diabetes and high blood pressure. People with history of the causes must take extra precautions to avoid kidney diseases.

When the waste from the body is not eliminated it means that the kidney is not functioning in ideal way and needs immediate attention. Ignoring the issue may lead to end stage renal disease (ESRD) which is a threat to life as it affects removal of waste & restoration of body fluid volume and compositions. Therefore some filtration process is needed to remove waste and keep the blood pure. This process is widely known as 'Dialysis'.

Dialysis may offer filtration process as a replacement of kidney but it does not provide a permanent replacement of kidney function unless a kidney transplant is done by the patient. There are advantages as well as disadvantages when a patient opts for dialysis. Dialysis may or may not cause nausea, poor appetite and loss of energy, weight loss, irregular menstrual periods, anemia and many other things in a patient. Apart from the above causes of dialysis it manages to offer a healthy life to patients with ESRD.

II. DIALYSIS AND ITS TYPES

Dialysis is a process of artificial filtration in case of kidney failure which eliminates the waste & unwanted water from the human body.

Dialysis can be done in two ways: (a) Hemodialysis, (b) Peritoneal Dialysis. In Hemodialysis, blood is sent through a cycler external to the human body to remove wastes and the clean blood is returned to the body. Whereas in Peritoneal Dialysis (PD), a fluid is put into the patients abdomen; this fluid absorbs the wastes present in the blood. After few hours, the fluid which consists of the body toxins is drained out from the abdominal cavity. This process is repetitive at regular intervals. Both the dialysis methods work in efficient ways to replace kidney function in human body with ESRD; but the choice is mostly left to patients.

Peritoneal Dialysis is being used as an alternative for hemodialysis since decades. There are two ways in which PD can take place: (a) Continuous Ambulatory Peritoneal Dialysis (CAPD), (b) Automated Peritoneal Dialysis (APD).

CAPD: This process does not use machine to complete the process instead, patient fills the stomach with dialysate and drain it out every 4-5 hours with the help of gravity. This process involves several exchanges in a day and hence may cause inconvenience for working people.

APD: This process uses a machine to performs the exchanges (instead of gravitational force) while the patient sleeps at night. The fluid is automatically filled in the cavity and the filtration process occurs in the abdominal cavity and the waste is drained out. The patient feels comfortable in this process due to its very flexible nature.

APD (a type of PD) is getting widespread with the forthcoming developments in this field. The motivation of this research is to educate people about APD and the flexibility it can provide to a person suffering from ESRD.

Principle of Peritoneal dialysis

Peritoneal Dialysis (PD) uses a small part of the abdominal cavity for artificial filtration; a semipermeable membrane called 'Peritoneum' which lines the walls of the abdomen & covers the internal organs. Peritoneum membrane consists of tiny microscopic pores that allows even small particles or molecules present in the liquid to pass through the membrane to another side; thus forbidding the particles larger than the holes in the peritoneum membrane to pass through.

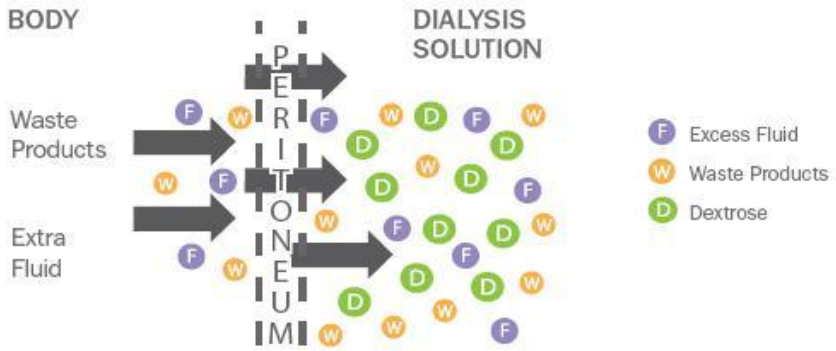

Figure (2) Semipermeable membrane 'Peritoneum' filters the wastes from the blood during PD when dialysate is present in the abdomen cavity.

Usually this process is done manually as the gravity works to get the fluid inside and then drain it out; this type of PD is called Continuous Ambulatory Peritoneal Dialysis (CAPD). But, APD uses an efficiently programmed machine to perform exchanges automatically as the patient sleeps at night. The time for which the dialysate remains in the body is called as 'dwell time'. In the day time, the stomach is filled with dialysate and it remains there for the whole day which is the maximum dwell time.

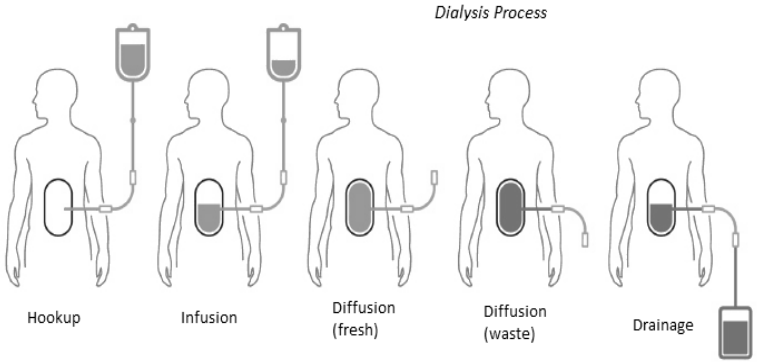

Figure (3) Process of Dialysis

The five steps are: (a) Hookup- the patient attaches its catheter to the dialysate fluid, (b) Infusion- the fresh fluid is entered in the abdomen cavity, (c) Diffusion (fresh)- The fluid stays in the abdomen for a period of time 'dwell time' for the processes osmosis & diffusion, (d) Diffusion (waste)- after the filtration is complete the waste fluid is collected in the cavity, (e) Drainage- fluid waste from the filtration present in the abdomen cavity is drained out of the body. And again fresh dialysate is filled in the abdomen cavity.

III. EXISTING SYSTEM FOR DIALYSIS

The available systems in the market for dialysis are mostly manufactured by Baxter International, an American health care company which focuses on products to treat kidney disease, hemophilia and acute and chronic medical conditions. Baxter Home Choice Automated PD system like many other electric equipment's, plugs into an electric socket. There is a guide book provided to easily understand the working of the machine by patients. A patient can have 4 to 5 bags of dialysate attached to the machine for the exchanges.

Proper training is given to the patients using these machine. Also a user manual is delivered incase if the user faces any problem with the machine. These systems have proved very efficient for the patients who have chosen this over traditional methods.

One major disadvantage of these systems is they are extremely expensive for regular people who cannot pay for buying such costly systems. And for the traditional methods, it becomes difficult to visit hospital 3-4 times a week for dialysis exchanges.

The cases with ESRD is increasing day by day, therefore it is necessary for the APD systems to give proper assurance to ESRD patients that they can have a flexible life. For that, there has to be a tradeoff between cost (especially NRE cost) and the selling price without hampering the accurate function of the dialysis machine. The cost of the machine can be reduced for the use of people who cannot afford home treatment.

Another disadvantage in the current APD systems pointed out by many patients is the presence of leakage current. This disadvantage can be eliminated by the addition of an additional circuitry for leakage current protection.

IV. PROPOSED MODEL AND METHODOLOGY

In the above section, the researcher discussed the existing model by Baxter International, which is a very popular system in the market; but with the major disadvantage of cost.

In the reference, the author Peter G. Blake has mentioned the one disadvantage of APD over CAPD is its higher cost. The expense consists of the capital cost of the cycler used in the filtration, plus the extra daily cost of additional dialysis solutions and tubing that is required in APD. The author also mentions that there are insufficient data for any sort of accurate cost-benefit analysis at that time, and issues in the programs had to be resolved.

Hence, to combat with the above disadvantages, this paper proposes a model for Automated Peritoneal Dialysis (APD) which is a cost effective system; can be efficiently used by any patient who chooses home automation. The paper consists of a finalized the block diagram and the design and working flow for the model. The proposed machine is PIC based circuitry due to which, it offers flexibility in programming.

Initially, the prescription of the patient is to be fed in the machine, he/she does not have to change the settings until the next prescription arrives. The patient just needs to connect the catheter to the machine and the machine will perform its operation in the stipulated time.

A. Block Diagram of APD machine

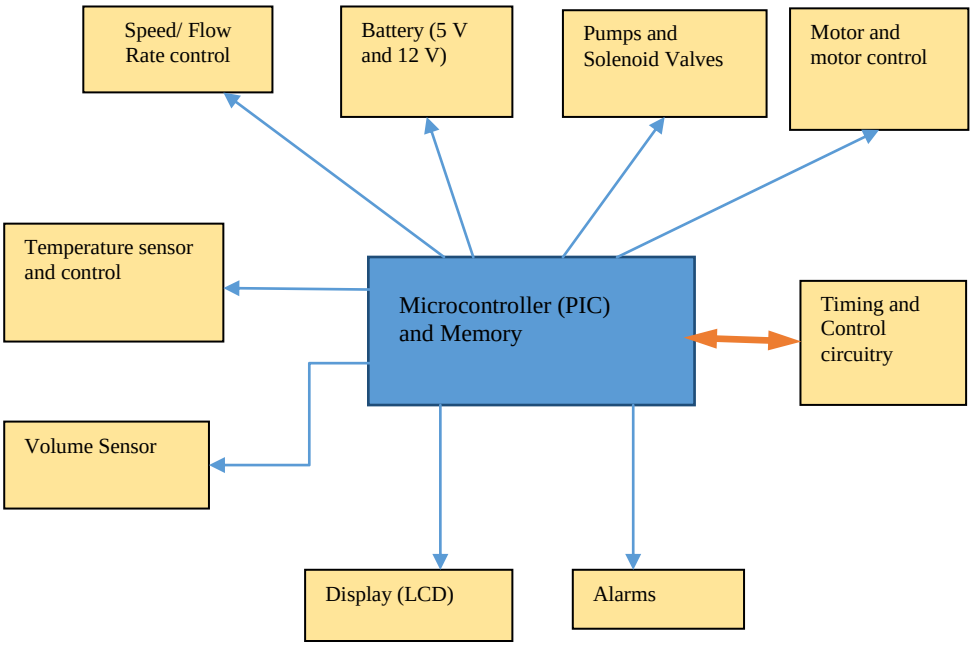

Figure (4): Block Diagram of the Proposed Model

The block diagram in the figure (4) is a PIC based circuitry and its peripherals as listed and explained below:

i. Temperature & Pressure Control: the dialysate filled in the abdomen cavity of the patient is to be heated at a temperature of 37 to 40 degrees. This is to be controlled and monitored as per the body temperature of the patient. Flow Rate Control: the rate at which the fluid enters the cavity should be uniform. A timing circuit is used to control the flow of dialysate in the body.
ii. Pumps: two pumps are required in the machine; one for pumping in the dialysate from the bag into the cavity and another from pumping out the waste from the cavity after diffusion of waste takes place. The function of pumps are controlled by PIC with the help of Motors (Solenoid Valves)
iii. Motors and Motor Control: motors control the complete operation of the system from flow control to pumping operations. Solenoid Valves are open-close circuits; when the dialysate is to be filled in the cavity, the motor opens the valve and then the pump pumps in the dialysate from the solution bag into the abdominal cavity; after that the valve is closed by the PIC by sending a pulse.
iv. Timing Circuitry: the timing circuit monitors all the operation since the machine is turned on, the process is carried out and it shuts off. It also gives alarms when the machine is On, Off or any error is identified during the process.
v. Microcontroller PIC: PIC is a very flexible microcontroller. Its features include- (a) ideal for motor control, (b) in-built 10 bit ADC and other features like low power consumption, good interface for communication buses (CAN, LIN, SPI, etc.), simplified for programming with hardware and software.

These are the features of the proposed design, a separate memory unit is to be added to save the results of the dialysis, which can be helpful to analyse the condition of the patient in the future. Another advantage of the machine is that it compares the amount of solution inserted in the abdomen cavity and the amount of storage drained and displays the net difference between the two volumes. This can help the doctor to know how efficiently the patient is responding to the treatment.

B. Flowchart

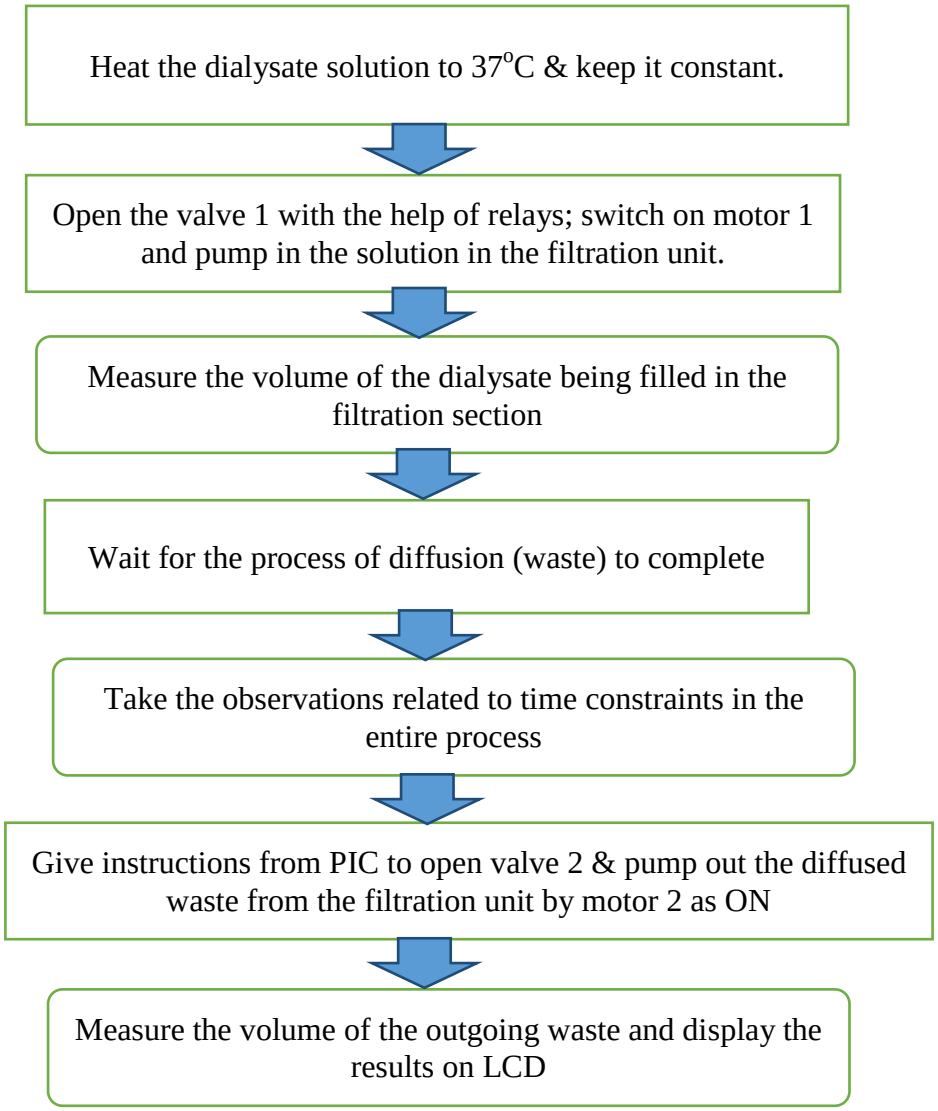

Figure (5) Flow of the proposed model

The proposed PIC circuitry as shown in figure (4), is to be mounted on a wooden platform with an arrangement of artificial kidney called the 'dialyzer' and the tubing for the process to take place. The flowchart describes guidelines to perform the process by the controller. The next section describes the working of the circuit in detail based on the flowchart, figure (5).

V. WORKING OF THE CIRCUIT

Initially the patient needs to connect the catheter from the body to the solution bag and then turn on the machine. The working of the circuit can be summarized as:

i. The machine or circuit when connected to a switch, the switch will trigger the power supply on the board which in turn will turn on the PIC. The PIC issues a pulse to the timing circuit and gives an alarm indicating that the machine is ON.
ii. Patient Monitoring unit takes the initial reading of the patient. The valve is closed for this time.
iii. The heated dialysate (37-40 degree) is then pumped into the abdomen cavity when the PIC sends a pulse to Solenoid Valve; which opens (open circuit) and the motor follows the pumping of the dialysate in the abdominal cavity.
iv. As soon as the required amount of solution is filled, the PIC issues another pulse to the valve which closes the valve. The fluid remains in the cavity for a certain amount of time called the 'dwell time': during the dwell time diffusion of waste takes place (as explained in the previous sections). This time fixed for a patient but it can vary for children, adults and senior citizens depending upon their capability of exchanges.
v. After the dwell time, Solenoid valve is again open circuit and the motor pumps out the waste fluid from the abdomen cavity.
vi. Fresh fluid is again filled in the cavity for the next exchange. This continues 4-5 times every night for 8-9 hours.

The machine won't make any noise while the process is on unless an error arises. This gives a patient a healthy and sound sleep. The proposed circuit works in this fashion to encourage people and give them motivation for life.

VI. CONCLUSION

There are many published articles which point out need of awareness among people about Automated Peritoneal Dialysis (APD) and how it provides a better and flexible lifestyle to ESRD patients. But the only major issue is that the available resources are expensive and hence not affordable to common man.

To undertake this issue, this paper emphasizes on the role of kidneys, their function and what happens if kidney function fails and types in which an ESRD patient can opt for dialysis treatments. Also the paper proposes a system for APD which is easy as well as cost effective. The system is flexible because of the use of PIC which efficiently monitors the connected circuitry and controls the various operation of the valves, pumps, motors, alarms, etc.

The advantages and disadvantages of APD are also discussed in the sections. Overall, APD machine is an efficient way to deal with ESRD problems.

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