Review of the Hemodialysis

Haemodialysis is a method for removal of impurities such as creatinine, phosphorous and potassium and urea, as well as free water from the blood when kidney failure. If the patient has kidney malfunctions the impurities are removed by using artificial means of a machine called haemodialysis. The procedure of dialysis is highly tedious and time consuming to the patients. The patients have to visit hospital frequently 1 to 4 times per week depending on the condition of their kidneys. The blood from the patient is removed from radial artery then sent to the dialyser for filtering. The filtered blood is sent back into the body through femoral artery. The dialysing procedure has its own risks and limitations such as fatigue, anaemia, formation of embolus and risk of infections. These drawbacks can be overcome by using a wearable kidney dialyser (WKD) which is a miniature form of dialyser machine. This can be worn as a belt hanging around the patient's waist. The wearable kidney dialyser contains pump system that draws blood in and out of the body, a dialysing unit, temperature monitor, pH meter, flow sensor, battery and a solar panel for extra power supply. The wearable artificial kidney is driven using batteries and solar panel for power generation. The wearable kidney dialyser can be worn continuously that will perform the function of natural kidney. The rate of filtration is 12ml/min in a synchronous manner. The advantage of the proposed method is slow and continuous process which may avoid fatigue and other complications. The patient no need of wasting their valuable time they can move around even during the dialysing procedure. Mobile application is developed to monitor all clinical parameters of the patient using android app to communicate the physician at remote distance.

India has a population of 1.2 billion and has shown a good economic improvement in the recent years. The globalization and urbanization have drastically altered the eating habits and lifestyle habits. This has become the cause of rapid spurt in the lifestyle-related diseases such as diabetes, heart diseases, hypertension and chronic kidney diseases (CKD). The CKD has now increased all over the world, with the global annual growth number of ESRD (End Stage Renal Disease) patients is 7%. The CKD is assumed as a significant death cause in most of the country, especially the economically backward countries due to high disease burden, expensive treatment and lack of awareness for prevention of disease. Estimates of ESRD burden in India is about 1,650,000 to 2,200,000 every year among the population of 1.2 billion. Out of which only 10% or fewer patients receive renal replacement therapy [1].

Healthy kidneys filter the blood impurities like excess fluid, minerals and wastes. When the kidney fails to function properly, harmful wastes build up in the blood that causes the body to retain more fluid and not make enough red blood cells. This should be immediately treated by replacing the work of the failed kidney through organ transplantation or haemodialysis.

Haemodialysis is a procedure of filtering the blood by drawing the blood out of the body and run it through a special filter that removes the wastes, minerals and salts. Then the clean blood is returned back to the body. The haemodialysis helps to control the blood pressure and keep up a proper chemical balance of the blood by filtering the unwanted minerals and salt from it. One of the major drawbacks is that the patient receiving this treatment should follow a very strict diet and schedule. The procedure is done 2 to 4 times per week depending on the severity and each session lasts up to 3 to 5 hours. Even with the best effort of adjusting to the effects of kidney failure, patients often face the difficulty in work and personal life [2].

The patient has to be attached to the machine during the whole procedure. The patient being tethered to the machine for 3 to 4 times a week for 3 to 5 hours each session will definitely cause the patient spend most of the time in the hospital that affects the quality of lifestyle and not able to proceed with their daily life. To overcome this disadvantage, the idea of developing a wearable artificial kidney was bought up by Kolff (1970's) to improve the quality of patient's life allowing them to move around freely even while the procedure is ongoing [3]. The wearable artificial kidney is a miniature dialysis machine that has been designed in such a way that it can be worn around the waist like a tool belt [4]. There are different types of wearable dialysis devices that are still under research stages. This device can be worn and used by the patient for up to 24 hours a day for a slow and gentle dialysis procedure, just like the natural kidney. This is the best way to mimic the biological renal functions and also due to its slow and continuous dialysis, the blood pressure is kept under control and reduce the need for phosphate binders and anaemia drugs.

The wearable artificial kidney developed so far is still under research and development process. The biggest drawback is the power supply, which goes out in the midst of the dialysis. Therefore to overcome that, we have included a solar panel, which charges acts as a power backup which allows the process to proceed even when the battery runs out of power. An app is also developed to monitor the parameters like pressure, flow and any change in the structure of the fluid. These parameters are transferred using Bluetooth to the mobile app which sends these values to the doctor's phone via an SMS. This will help greatly in monitoring the patient by a doctor at a distance. The solar panel provides the power to run the device when the battery runs out, thus the dialysis does not stop in the middle.

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The wearable artificial kidney mimics the natural kidney function with slow and continuous filtering process. The whole device is attached to a belt so that the patient could move freely whilst the procedure. The device contains a special filter that is used to filter the blood, a pump, flow sensor, pressure sensor, an IR sensor, a LED display, relay, solar panel, pH meter, battery, Bluetooth and ARDUINO. ARDUINO: ARDUINO is a single board microcontroller that is used to

make the electronics in multidisciplinary projects which is more accessible.

Hardware-consists of a simple open source hardware board that is built around 8-bit Atmel AVR or 32-bit Atmel ARM.

Software- consists of a standard programming language compiler and a boot load that is used to execute the microcontroller LCD DISPLAY: The LCD display consists of a liquid crystal material sandwiched between two transparent glass sheets. LCD displays are usually thin in diameter, lightweight and less power consuming hence can be used in low power projects and can be run for the long time with less power consumption. It is usually used in watches, calculators and other measuring instruments.

RELAY: A relay is an electrically operated switch that usually uses an electromagnet to mechanically switch the relays. But other principles such as solid-state relays are also used. Relays are used in the electrical circuit to protect them from heavy loads and faults. In modern electrical circuits, a digital instrument called ‘protective relays’ perform these functions.

DC PUMP: A micro oil/water circulation pump is used to deliver the liquid to be dialysed in and out of the machine. It can be continuously used, withstands high fluid temperatures and has low noise level.

SOLAR PANEL: A solar panel is made of a group of solar cell that is capable of converting sunlight into electricity. Solar power has a wide range of uses ranging from its usage in watches, calculators, roadside lightings to powering buildings and solar planes. The cells are made of a semiconductor material, often silicone is used. There are 2-layers of silicone in a solar cell that is n-type and p-type. The electricity is produced by the light entering the cell, the silicon absorbs a part of the light. The light’s energy knocks off the electrons out of the atoms, thus producing electricity because of the flow of electrons between two layers. The electricity can leave the cell by metal contact wires.

FLOW SENSOR: The flow sensor has a small rotating fan encased in a chamber that rotates when a fluid flows through the sensor. The speed of rotation is measured, which is directly proportional to the flow of the fluid. The flow of blood is kept slow and steady so that it encourages effective filtration process.

DIALYSER CHAMBER: The dialyser chamber is the part where the actual filtration process takes place. The chamber contains a bundle of hair like thin hollow fibres. The blood flows inside of these fibres in one direction and the dialysate fluid flows outside of these fibres in the chamber. This opposite flow direction and the concentration gradient between the blood and dialysate fluid enables the filtration process. The hollow fibres act as a semi-permeable

membrane and the minerals, urea, phosphate from blood moves into the dialysate fluid due to the concentration gradient.

RESORBANT CHAMBER: The dialysate fluid gets contaminated with all the toxins and minerals that moved from blood to the fluid. Hence it needs to be purified before entering into the dialyser chamber again for filtering blood. This chamber contains activated carbon packed in it which absorbs the minerals and toxins from the dialysate fluid when passed through the chamber. Hence pure dialysate fluid is supplied every time to the dialysis chamber.

BLUETOOTH AND MOBILE APPLICATION: The parameters of the sensors such as flow and pressure that was displayed on the LCD screen is also sent to a mobile application through Bluetooth. These values are then sent to a doctor's phone through an SMS. This enables the doctor at the hospital to monitor the patient at home so that the patient does not have to travel to the hospital unnecessarily.

A blood substitute is used instead of blood that represents a very close similarity with natural body fluid. The dialysate fluid used is a mixture of sterile water with bicarbonate salts and sodium chloride. The blood substitute is pumped into the dialysis chamber, where filtration takes place. The flow and pressure of the fluid are measured using the sensors. The pH is measured before and after filtration to ensure the purification has been done. The power provided is from a 9V battery and a solar panel will provide a power backup.

The solar power backup provides with the power to run the device after the battery runs out so that the process does not stop in between. The monitoring features are developed by providing with a display that shows the measured value, which greatly improves the patient's secured feeling by monitoring the parameters. The mobile app enables the doctor from the hospital to monitor the patient under dialysis at home that brings telemedicine technology in the process. The pH measurement ensures the chemical balance of the fluids, so that abnormality can be checked and fixed by either replacing the dialysate fluid or the resorbing chamber. The patient's quality of life is greatly improved by allowing them to proceed with their daily life even during the procedure, which is the main goal of any wearable dialyser techniques.

A prototype for the wearable kidney dialyser with solar power generator was successfully developed. The battery-powered wearable dialyser will stop the dialysing procedure in between if the battery runs out of power. But the solar power backup that is used in the proposed system provides power to run the device when the battery is drained. This way the procedure does not have to stop in between to replace the batteries. The monitoring system is improved by using an LCD display to show the measured value of flow and pressure. The mobile app also helps the patient to get an opinion from the doctor at a distance. Future developments will be made to reduce the weight of the device, an even more feasible way of monitoring and more rigid tubes

to avoid kinking.