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Portable Kidney Machines

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ABSTRACT: Renal failure is a term to describe a situation when the kidneys fail to work. This may be a permanent or temporary failure. When the kidneys fail, Wastes begin to accumulate in the blood (uremia)As homeostasis is upset within the body, other organs can also begin to shut down – heart, liver, etc. The end result of renal failure is usually death unless the blood is filtered by some other means. The ideal intervention is to replace the failed kidneys with a donor kidney (STSE).While a person waits for a donor kidney, they usually have to undergo *dialysis*, a method where their blood is filtered and cleaned on a regular basis using machines. This paper gives a brief review about home dialysis machines.

Keywords:uremia, homeostasis, dialysate, British Pharmacopoeia.

I. INTRODUCTION

The main stages that blood passes through during the dialysis process includes[1]Blood enters machine from body (under pressure from radial artery)then it is sent to the Pump (some diagrams show a roller pump) controls pressure and flow rate. The Anticoagulant is added to prevent clotting. The Blood then passes through dialysis membrane (equivalent to kidney nephrons).The Bubble Trap then removes any gas bubbles from blood.Blood is filtered then returned to the patient's radial vein.

II.TYPES OF DIALYSIS

There are two types of Dialysis namely

A. Peritonial dialysis:

Peritoneal dialysis (PD) [2,6]is a treatment for patients with severe chronic kidney disease. The process uses the patient's peritoneum in the abdomen as a membrane across which fluids and dissolved substances (electrolytes, urea, glucose, albumin and other small molecules) are exchanged from the blood. Fluid is introduced through a permanent tube in the abdomen and flushed out either every night while the patient sleeps (automatic peritoneal dialysis) or via regular exchanges throughout the day (continuous ambulatory peritoneal dialysis). PD is used as an alternative

to hemodialysis though it is far less commonly used in many countries, such as the United States. It has comparable risks but is significantly less costly in most parts of the world, with the primary advantage being the ability to undertake treatment without visiting a medical

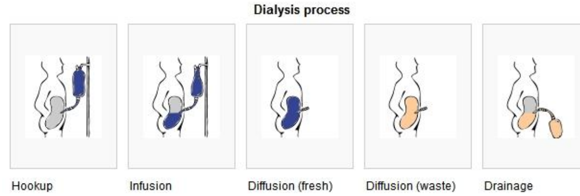

Fig 1: Dialysis Process

facility. The primary complication of PD is infection due to the presence of a permanent tube in the abdomen.

B. Hemo dialysis

The principle of hemodialysis[3,6]is the same as other methods of dialysis; it involves diffusion of solutes across a semipermeable membrane. Hemodialysis utilizes counter current flow, where the dialysate is flowing in the opposite direction to blood flow in the extracorporeal circuit. Counter-current flow maintains the concentration gradient

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across the membrane at a maximum and increases the efficiency of the dialysis.

Fluid removal (ultrafiltration) is achieved by altering the hydrostatic pressure of the dialysate compartment, causing free water and some dissolved solutes to move across the membrane along a created pressure gradient.

The dialysis solution that is used may be a sterilized solution of mineral ions or comply with British Pharmacopoeia. Urea and other waste products, potassium, and phosphate diffuse into the dialysis solution.

However, concentrations of sodium and chloride are similar to those of normal plasma to prevent loss.

Sodium bicarbonate is added in a higher concentration than plasma to correct blood acidity. A small amount of glucose is also commonly used.

Fig 2.Haemodialysis Machine

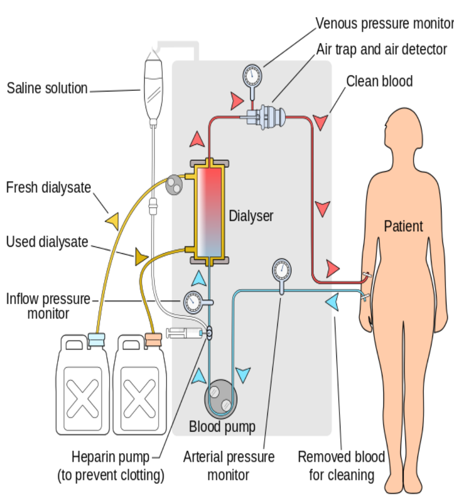

Fig 3.Haemodialysis Process

III.DIALYSIS MACHINES OVERVIEW

Dialysis machines are artificial kidneys that perform most, but not all, kidney functions for patients who have permanent or temporary renal failure. The machines use hemodialysis cleanse the blood and balance its constituents. With this process, the patient's blood is circulated through the machine where it is filtered and balanced for electrolytes, pH, and fluid concentration before being returned to the patient. One common problem with renal failure is water retention, so it is common for the process to remove several pints of fluid from the patient's blood. There are two basic classes of dialysis machines: clinical units, which are commonly cabinet-size machines operated by trained technicians; and home-use dialysis machines, which are smaller and sometimes portable. Normally, patients with complete loss of kidney function would need to visit the clinic at least three times per week and spend about four hours connected to the machine. With home-use machines, patients have more flexibility in scheduling dialysis, and they can dialyze for longer periods and more frequently. Thus, home-use machines are growing in popularity because they offer greater convenience and better clinical outcomes.

IV. GENERAL OPERATION OF DIALYSIS MACHINE

The patient's blood is continuously pumped from an artery, a large vein, or a surgically modified vein to allow high blood flow rates. Its pressure isboth upstream and downstream from the peristaltic blood pump. Before the blood enters the dialyzer, heparin is added to prevent clotting. A syringe pump is used to deliver the heparin at a precisely controlled rate. The blood then enters the dialyzer where it passes across a large surface-area, semipermeable membrane with a dialysate solution on the other side. A pressure gradient is maintained across the membrane to ensure the proper flow of compounds out of and into the blood. After cleansing and balancing within the dialyzer, the blood is passed through an air trap to remove air bubbles before it is returned to the patient. An air bubble sensor ensures that no air bubbles remain. Blood-pressure, oxygen-saturation, and sometimes hematocritlevels(blood cell concentration) are monitored for proper operation of the machine and to ensure patient safety.

Fig.4.Clinical dialysis machine

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V. PORTABLE DIALYSIS MACHINE (PORTABLE KIDNEY MACHINE)

Fig5 . Portable Dialysis Machine(Maxim Model)

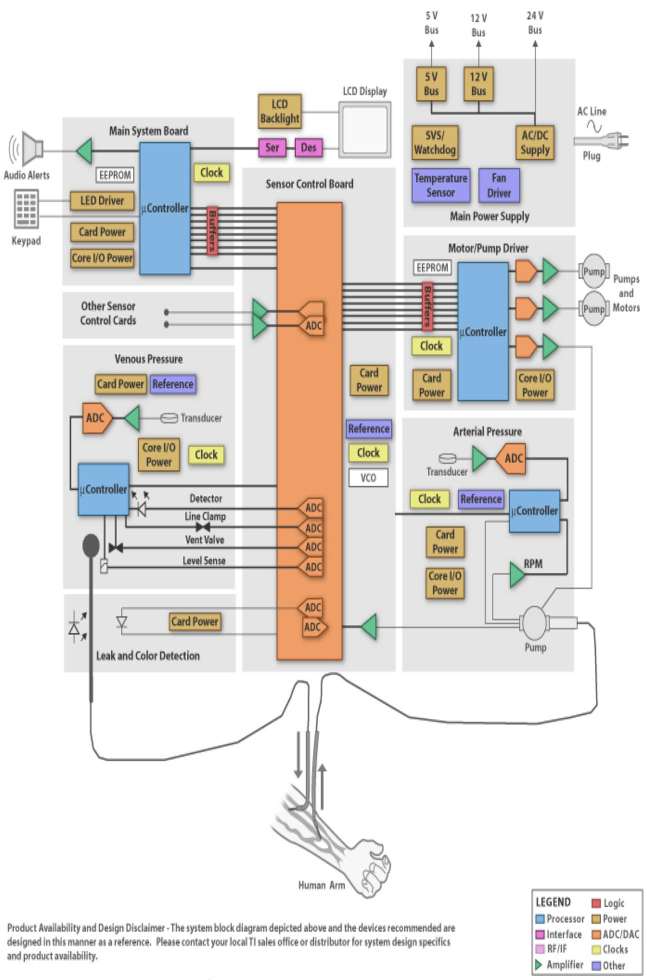

Fig6 . Block Diagram of the Portable Dialysis Machine (SBD 6217, Texas Instruments, India)

VI. DIALYSATE CIRCUIT

In clinical settings, dialysate is usually premixed to the proper concentration for direct use. In home units, to keep container size down, concentrated forms of dialysate are often used and diluted with sterilized water in the machine. Thus, home units must include water heaters, valves, pumps, and a variety of sensors to perform these extra steps. To lower power consumption in home units, the dialysate preparation process is often performed ahead of time, separately from dialysis[4].

Both types of machines include capabilities to add a bicarbonate buffer solution to the dialysate.

VII. DISINFECTION CIRCUIT

After the dialysis procedure, the machine must be cleansed and sterilized. Provisions are made in the plumbing to close the circuit into a loop and run saline and/or sterilized water through the system to flush away all impurities.

VIII. SPECIAL REQUIREMENTS OF HOME UNITS

For general convenience, home systems are smaller and sometimes portable. Since they require the additional function of dialysate preparation, the need for small, compact design is increased over clinical machines.

The disinfection cycle at the end of therapy is also a power-hungry process. To accomplish the heating required in a reasonable amount of time, batteries or ultra-capacitors are included to provide short-term high-power capability to supplement line power as needed. When line-power usage drops below the 15A limit, the batteries or ultra-capacitors are recharged

IX. MACHINE FEATURES

C. Display and backlight

Clinical dialysis machines commonly have relatively large displays (approximately the size of a computer screen), while home units have much smaller displays. Modern machines normally employ a graphical user interface (GUI) for ease of use. They use liquid-crystal displays (LCDs), instead of cathode ray tube (CRT) monitors, to reduce weight and power consumption[4].

Maxim supplies LVDS serializers and deserializers uniquely suited for LCD panels. These solutions cover a wide range of bit widths (from 1 to 27) and speeds up to 2.5Gbps. They can translate between different logic levels (e.g., from LVCMOS to LVDS) to ensure compatibility between the processor video interface and the display module.(Refer Fig 4. And Fig 5)

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D. Touch screens and keyboards

Maxim offers a variety of keyboard scanners, including devices that allow multiple simultaneous key presses. In many applications, keyboards are being displaced by touch screens, which can improve the user experience when paired with an intuitive GUI.

E. Data Interfaces

A running record of the dialysis process for each patient session is kept electronically and made available in a number of ways. Dialysis machines can include USB, Ethernet, and a variety of serial (RS-232, RS-485, RS-422, etc.) interfaces to legacy hospital information systems. Wireless interfaces (such as Wi-Fi®) may also be included for direct connection to hospital wireless networks.

X. MECHANISM

F. Pumps.

Peristaltic pumps are commonly used for driving the various higher volume fluids in the machine: blood, dialysate, water, and saline. This type of pump is very convenient because it does not touch the fluids directly. Instead, a section of flexible tubing runs through the pump mechanism where it is compressed by rollers to push the fluid forward. These pumps require a significant amount of power and are driven by either DC or AC motors with variable speed control. Electronic means must be provided to ensure that the motor is turning at the desired rate. Maxim has Hall-effect sensors that give a fully independent signal picked up from actual shaft rotation, which can be used for redundancy if the motors already have Hall-effect sensors built in. For the lower volume fluids such as heparin, a syringe pump mechanism is commonly used driven by a small stepper motor or DC motor. Precise measurement of proper mechanism advance is needed.

G. Valves.

Several valves with electronic actuation are needed in the machine to allow variable mixing ratios. Various implementations are possible from simple opened/closed valves driven by solenoids to precision variable-position valves driven by stepper motors or other means.

I. Cleaning system.

Between patient sessions, any reused components must be sterilized. One approach is to heat water or saline to a high sterilizing temperature and then run it through the machine, both through the extracorporeal circuit and through the dialysate circuit. Whatever cleaning mode is used, the machine may require additional driving and monitoring for proper operation.

J. Processing

Because of the large number of input signals to be monitored and the large number of pumps and other mechanisms to be controlled, many of these functions are performed with dedicated microcontrollers for that portion of the system. Controlling the overall system will be a main processor capable of running a full operating system and GUI. Communication between the controllers is required to send data, commands, and alerts.

K. Fail-safe circuitry

ICs with self-test and fault-reporting capabilities are very useful for maintaining patient safety under single-fault conditions. Additional monitoring circuitry is commonly used to monitor power-supply voltages, while watchdog circuits are used to ensure that microprocessor operation remains within bounds. Both audible and visible alarms are provided to alert users when a warning is needed or a fault condition has occurred.

L. Power Supply

Due to the long duration of the dialysis process, all dialysis equipment is AC-line powered. Standard AC-DC converters meeting medical safety standards are employed. Due to the variety of components requiring power, a variety of voltage rails are needed at different power levels. A power system with multiple-output switching regulators is needed with a significant amount of linearregulation at the load for noise-sensitive precision circuits.

Safety regulations require power-supply self-monitoring for voltage, temperature, and current flow. Overvoltage and under voltage detectors are common. Due to the higher power levels, active cooling is required using fans and temperature sensors in a variety of locations. Home-use machines include water sterilization capabilities, which can require more power than is available from a standard wall outlet at 15A. Therefore, the power supply must be capable of limiting the current drawn from the AC line and adding in parallelpower from a battery (or ultra-capacitor).

M. Battery Management

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As discussed above, home-use dialysis machines need to include batteries (or ultra-capacitors) to supplement the power supply's output power when heating water for sterilization. These must be charged whenever possible and fuel gauged to indicate when enough capacity is available to proceed with the water sterilization process.

XI.ADVANTAGES

1. Include capabilities to add a bicarbonate buffer solution.
2. Patients with complete loss of kidney function would need to visit the clinic at least three times per week and spend about four hours connected to the machine. With home-use machines, patients have more flexibility in scheduling dialysis, and they can dialyze for longer periods and more frequently.
3. Low-power design.
4. Wireless interfaces (such as Wi-Fi®) may also be included for direct connection to hospital wireless networks.
5. Data card slots are also available on some designs. This allows patients to carry an ID card with personal medical information stored on it to enable automatic setup of many of the machine parameters.

XII. COMPARISION

Manufacturers	Texas Instruments	Maxim	GenetixBiotex Asia Pvt. Ltd.
Model No.	SBD6217	MAX3803	
Ram (Bytes)	2048	8192	
DAC Resolution (Bits)	12	12	8
No.of DAC	2	2	2
Temperature Sensor	Yes	Yes	Yes
Description	16 bit ADC, ultra-low power MCU, 60KB flash, 8KB RAM, Dual DAC,DMA, 3 OP AMP, 128 Seg LCD	6 Bit ultra-low power MCU, 16 Kb Flash, Single DAC,DMA,160Seg LCD, Wi-Fi Enabled.	MSP430FR573x,MSP430FR572x Mixed Signal Microcontroller
Price (In Lakhs)	5.25	8.35	2.25
Frequency (in MHz)	8	8	24
Other Specifications	2 DAC, 3 op-amp, Comparator,DMA SVS	2DAC,Multiplexer,SignalConditioner, DMA,SVS,2 Comparator	DAC12, Op Amp
Wi-Fi Connectivity	No	Yes	No
Digital Display	Yes	Yes	No
Touch Screen Display	No	Yes	No
Signal Processing Speed (in Gbps)	2.5	3.2	2

TABLE I: Comparison table of leading Manufacturers

The MECS Dialyzer[9] are being used inthe portable daialysis machines because of the following advantages.Carommercialization Micro engineered dialysate compartments and has the same urea clearance as a conventional dialyzer 4 x the size. It reduces the required mass transfer area and dialysate flow rate.This shows no significant blood damage in Hematocrit and plasma free hemoglobin tests The present invention is related to hemodialysis, and more particularly, to a dialyser with improved efficiency of mass transfer across a dialysis membrane utilizing microchannel separation provided in accordance with embodiments of the present invention. In accordance with an embodiment, a dialyzer is provided comprising a plurality of semipermeable membrane sheets and a plurality of flow separators. The membrane sheets and flow are arranged in alternating configuration and coupled into a laminae stack defining a plurality of parallel microchannel layers. Each microchannel layer comprises a

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plurality of first microchannels and a plurality of second microchannels. The first and second microchannels of each microchannel layer are in fluid communication with each other via one of the plurality of membrane sheets therebetween. The MECS dialyzer is characterized as having a high surface to volume ratio and a high mass transfer coefficient.

XIII. CONCLUSIONS

The Maxim Model is better when compared to the other models because of the following reasons. This Model has a very good sensitivity. The Frequency range of operation about 8 MHz. The Temperature operation range of about -40 to 85 deg. centigrade and Sensor and the price of the instrument is also affordable**.** Wi-Fi Connectivity is also being implemented in this device.

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