Sally Askew and Rebecca Mathew

The Internal Artificial Kidney

**Abstract**

Our goal is to design a miniaturized internal artificial kidney. This kidney would be made in substitution of waiting for a donated kidney. Many people have kidney failure and need a new kidney pronto. With a miniaturized internal artificial kidney, the wait will be shorter and the artificial kidney would be able to perform the necessary functions of a normal kidney. The website lkdn.org says, “There are over 80,000 people on the kidney transplant waiting list. The waiting list has doubled in size over the past 10 years - and it continues to grow.” This shows evidence that a real kidney takes too long to wait for. Also the size of the kidney would be smaller and fewer supplies would be necessary in making the artificial kidney. This would be a benefit in helping our planet Earth.

**Present Technology**

There are various inventions of artificial dialyzers using numerous ways to extract any waste from the blood stream. Each dialyzer carries out the same function as the biological kidney. There are two types of artificial dialyzers Peritoneal, and Hemodialysis.

Peritoneal dialysis fills the patient’s abdominal cavity with dialysis solution, which contains dextrose. The dextrose pulls excess fluids and waste products into the space of the abdomen through the peritoneum (lining of the abdomen). The peritoneum acts as the membrane to separate the toxins and excess fluids that are excreted from the surrounding capillaries and veins of the abdomen. Next the dextrose is drained and with it, the wastes that were extracted from the blood stream.

In Hemodialysis, on the other hand the blood is pumped out of the bloodstream into a dialyzer and then pumped it back into the body. To begin the treatment the patient has to have an access location created in the body to withdraw the blood, usually in the form of a fistula, graft or catheter. A fistula is the most common and effective procedure, in which an artery in the arm is conjoined with a vein under the skin to increases size and blood flow of the vein. A Graft conjoins the same veins as a fistula, but meshes both with a plastic tube. A last resort is a catheter (because of their higher risks of infection than fistulas or grafts). After a point of access has been created, the blood is pumped out of the artery, and then into a dialyzer about an ounce at a time. The dialyzer is constructed of two parts, a section for blood and a section for dialysate, a membrane sections off the two parts. Blood is then collected in the dialyzer and begins to be filtered through the membrane. Blood cells, proteins and other important cell parts stay in the blood because they are too large to pass through the membrane. The waste products and extra fluids from the blood are small enough to pass through the membrane. These waste products are then disposed of, similarly to how your kidney disposes waste products that are filtered out of you blood.

Peritoneal and Hemodialysis both have negative effects. After Peritoneal dialysis, patients can suffer from infections in the abdomen cavity and the access site of the catheter. Patients can experience weight gain throughout the treatment due to large amount of sugar (dextrose) entering the body, this can lead to high blood sugar for diabetic patients. Hernias in the peritoneum can also be a result of holding fluids in your abdomen for long periods of time (the process of peritoneal dialysis). Hemodialysis has more risks then peritoneal dialysis. The most common side effect among patients is low blood pressure. Most serious is anemia, anemia is when there is a low number of red blood cells; this can result in poor absorption of iron. You can also suffer from bone weakening because you do not have as much vitamin D to absorb calcium. The condition Amyloidosis is common in patients who have received hemodialysis for more than 5 years; this is when proteins from the blood deposits on joints and tendons, causing stiffness and pain.

 Both peritoneal dialysis and hemodialysis function as artificial kidneys. The technologies share the principles of passing untreated blood through a membrane and then disposing of the toxins. Although both inventions cannot fully replace a human kidney, these machines can save lives of people suffering from kidney failure.

**History of Technology**

Blood dialysis is the cleansing of the blood inside a person’s body. The development of this technology started in 1861 by Thomas Graham, evolved in 1924 by George Haas, made additional improvements in 1943 by WJ Kolff and H Berk.

Decades ago, dialysis monitors were larger and needed manual controlling by a dialysis nurse. The process of a dialysis monitor two decades ago consists of various steps controlled by the dialysis nurse. The machines today are not in need of any assistance. In 1861 Thomas Graham found a method to extract urea from urine and called it dialysis. He realized that crystalloids are able to diffuse through vegetable parchment coated with albumin. The albumin acted the same as a semi-permeable membrane such as found in the kidney’s own cells. The role used of membranes is to surround and protect what enters and exits the inside of the body. After a change of patients with a low serum albumin, a survival benefit of 37% has been shown from high- flux dialysis.

In 1924 George Haas performed the first successful human dialysis. The patient had terminal uremia. There were no complications within the 15 minute procedure.

In 1943 the first human hemodialysis machine was developed by WJ Kolff and H Berk. The machine consisted of cellophane tubing in a stationary tank. Dialysis monitors today are smaller, portable, cause less human errors, and reduce labor costs.

Blood dialysis is a major importance for the body’s health. The dialysis monitor decades ago have been changed to a more efficient and portable system today. The current membrane development has changed to a multilayered membrane. In the years of 1861, 1924, and 1943 was the first mention of dialysis to the science of medical life. Polymer chemistry is the study of synthetic macromolecules and has enhanced by the improving dialysis monitors and the current membrane development.

**Future Technology**

The internal artificial kidney would be very similar to a human kidney. The artificial kidney would receive unfiltered blood from the renal artery. The unfiltered blood would then be passed through the membranes. There are three layers of membranes in the artificial kidney. The membranes stack one over another and block the toxins and waste from passing through the screens. The toxins and wastes that are too big, collect at the bottom of the kidney and are transferred through a tube into the ureter and then to the bladder. The healthy blood is transferred into a tube attached to the renal vein and then pumped back to the heart.  Another tube is attached to the aorta releasing hormones and vitamins into the bloodstream such as vitamin D and the hormone Corticosteroid.

**Breakthroughs**

An internal artificial kidney can benefit a patient’s life but is not able to be invented due to various reasons. Major breakthroughs that would have to be invented are: remove drugs from the body, balance the body's fluids (such as salt, potassium and acid content), release hormones that regulate blood pressure, produce an active form of vitamin D that promotes strong and healthy bones, and control the production of red blood cells. Moreover the technology would have to miniaturized compared to the current technologies. Additionally the kidney would have to be attached to the bladder allowing the waste to exit the body. The kidney would also have to be attached to the blood stream allowing it deliver its chemicals to the body and receive unfiltered blood. The hormone that regulates blood pressure is called Corticosteroid. A way to create this hormone is to recreate the compounds. An experiment could be conducted testing if it is possible to recreate the steroid by putting together its compounds into one substance and then putting it into the Internal Artificial Kidney. Even if the hormone could be made, it would have to be renewed at a certain point because it cannot reproduce on its own.



**Design Process**

 Throughout the process of designing the internal Artificial Kidney, we came up with various ideas to improve medical technologies. At first we considered pursuing research on Stem Cell Transplant technologies, but we discouraged the topic due the complexity of the information and our lack of knowledge in the field. Secondly we debated whether to continue research with Kidney Dialysis or Kidney Transplants. We decided to continue with Kidney Dialysis due to the many inconveniences patients face while dialyzing blood. Ultimately our final technology was a combination of Kidney Transplants and Kidney Dialysis.

 Before we decided on creating an Internal Artificial Kidney, we had three other ideas as well. Our first idea was to design a machine that creates radiation to kill waste, excess fluids and toxins. We decided not to do this technology because it could cause pain and it was not a mobile treatment. The second idea was to create a consumable pill that contained dialysis solution. We steered away from this technology because of the difficulty to remove the toxins from the body. Lastly we had an idea for a pocket sized dialysis monitor. This idea ended up being meshed with our idea of the Internal Artificial Kidney and helped us begin the process of creating this future technology.

**Consequences**

 There are various consequences if a person uses an internal artificial kidney. Some consequences of the artificial kidney include blood clots that happen due to a fewer amount of enzymes that are needed to dissolve the clots. Another consequence of an internal artificial kidney is that there may be a blockage in the urea removal. This occurs because the kidney functions may be slower and the filtered substances of the kidney may block waste removal. The destruction of cells is also a consequence. As the blood passes through the artificial kidney, the mechanical shear in the flow system destroys the cells by breaking them apart. Red blood cells, white blood cells, and platelets are damaged through this process which is also known as hemolysis. A layer of white cells deposits on a layer of the membrane when blood flows through the artificial kidney. This is a consequence because the white cells collect in that one spot when they are needed elsewhere in the body. All these consequences can be harmful to a patient using an internal artificial kidney.

An internal artificial kidney also has many positive consequences. This could eliminate the wait for a kidney transplant; the time spent using a dialysis monitor, and the necessity to carry a dialysis monitor. The internal artificial kidney could eliminate the wait for a kidney transplant by not having to wait for a kidney and avoid immune problems from another person. Rather you would have to wait little to have your kidney made. The time spent using the dialysis monitor consumes valuable time from the patient’s life. While using an internal artificial kidney you can travel and go to work while dialyzing your blood. Using a dialysis monitor limits your abilities to travel places. With an internal artificial kidney you can travel without your monitor and additional supplies. An internal artificial kidney could benefit a patient suffering with kidney failure greatly by conserving time and creating more freedom.

**Bibliography**

Boland, Edward W. "CLINICAL OBSERVATIONS WITH 16a-METHYL." Group.bmj.com,

n.d. Web. 16 Jan. 2013. <ard.bmj.com>.

"Dialysis." *Dialysis*. Davita, 04. Web. 10 Dec. 2012.<<http://dpc.convio.net/media/dialysis.html>>.

Health. Photography. Encyclopædia Britannica Image Quest. Web. 9 Jan 2013.

 *Hemodialysis.* 2012. 7 November 2012. <http://www.kidney.org/atoz/content/hemodialysis

.cfm>

*Hemodialysis.* June 2008. 7 November 2012. <https://www.healthinfotranslations.org/

pdfDocs/Hemodialysis\_SOM.pdf>

*Kidney Structure.* Illustration. *Encyclopædia Britannica Image Quest.* Web. 9 Jan 2013

"Maintaining the Body's Chemistry:Dialysis in the Kidneys." *Kidney Dialysis*. Washington

University, 5 Sept. 08. Web. 3 Nov.2012. [http://www.chemistry.wustl.edu/~edudev /LabTutorials/Dialysis/Kidneys.html](http://www.chemistry.wustl.edu/~edudev%20%20%09/LabTutorials/Dialysis/Kidneys.html)

"National Kidney and Urologic DiseasesInformation Clearinghouse (NKUDIC)." *Treatment*

*Methods for Kidney Failure: Peritoneal Dialysis*. The National Kidney and Urologic Diseases Information Clearinghouse, 2 Sept. 2010. Web. 04 Jan. 2013. <http://kidney.niddk.nih.gov/kudiseases/pubs/peritoneal/>.

The Renal Unit of the Royal Infirmary of Edinburgh. "History of Dialysis and Transplantation in

Edinburgh- Contents." *History of Dialysis and Transplantation in Edinburgh- Contents*. N.p., Oct. 2001. Web. 17 Jan. 2013. <[http://renux.dmed.ed.ac.uk/EdREN/Unitbits/ historyweb/history.html](http://renux.dmed.ed.ac.uk/EdREN/Unitbits/%20historyweb/history.html)>.

"renin." *Encyclopædia Britannica. Encyclopædia Britannica Online Academic Edition*.

Encyclopædia Britannica Inc., 2012. Web. 28 Nov. 2012. <[http://www.britannica.com/ EBchecked/topic/498133/renin](http://www.britannica.com/%20EBchecked/topic/498133/renin)>.

Staff, Mayo Clinic*. Definition*. 11 December 2011. 7 *November* 2012. <http://www.mayoclinic.

com/health/peritoneal-dialysis/MY00282>

*Treatment Methods for Kidney Failure: Peritoneal Dialysis*.7 December 2012.

<http://kidney.niddk.nih.gov/kudiseases/pubs/peritoneal/#top>

Undefined. "basic oval bowl." *Libby*. undefined. Libby Glass Inc. January 9 2013.

<http://foodservice.libbey.com/>.

undefined. " Dialysis Methods for Protein Research." Thermo Scientific. undefined. Thermo

 Fisher Scientific Inc. . January 9 2013.

*What is Dialysis Technology*. 2008. 7 November 2012. <http://www.healthcareers.net/what-is-

dialysis-technology/>.

**Webpages**









