College of Engineering
UNIVERSITY OF GEORGIA

Capstone Senior Design Project Abstract

Project Title: Bioartificial Liver Support Device

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The liver is an organ that is vital to the human body's metabolism. Because of this, any liver failure or significant loss of hepatic function could prove fatal to a patient. Due to the complexity of the liver, a liver transplant is the only current viable option to completely ensure that the patient will not succumb to liver failure. The goal of this project was to propose and develop a concept design for an extracorporeal bioartificial liver support system. Prior to designing a device, extensive background research on liver function and failure was compiled. Important stakeholders in the project were consulted in order to determine the design qualifications that the concept must meet. The most heavily considered requirements that the design must meet include maintaining at least 10 percent of normal liver function, filtering the blood, and supporting an adequate patient quality of life. Using these specifications, further research on current devices and therapies was conducted in order to see if there was anything currently on the market that could meet the given criteria. No current device is able to meet all of the client requirements, which gives ample evidence that a novel device must be designed.

Throughout the design process, several different potential devices were evaluated; the most important of which being a fluidized bed reactor, a hollow fiber membrane bioreactor, a packed bed reactor, and a centrifugal device. To choose between the different options, a decision functional diagram was created. From this diagram, it was decided that a packed bed reactor containing hepatocyte cells would best accomplish all goals. Hepatocyte cells make up approximately 80% of liver cells, making them largely responsible for completing essential functions of the liver. Using polyvinyl formal (PVF) resin, the hepatocyte cells can be attached within the reactor in order to filter the blood from a patient suffering from acute liver failure. Using the client specification that the device should maintain a minimum of 10 percent of normal liver function, it has been initially determined that the density of hepatocyte cells within the packed bed should minimally be 1.2×10^{7} cells per cubic centimeter of resin. With a resin volume of 1333 cubic centimeters, there are approximately 1.6×10^{10} hepatocyte cells within the reactor. While hepatocytes are responsible for producing bile in a normally functioning liver, the amount produced by 10 percent of the regular number of hepatocytes within the human body is considered negligible.

With the amount of bile leaving the device ignored, the design becomes much simpler. Whole blood exits the patient through a central venous line, passes through the packed bed reactor, and the filtered blood is returned to the body. Pressure drop calculations have also proven that a pump is not necessary for proper blood flow through the device, which also negates the need for any energy balance for the process. To develop a mass balance, it is convenient to define the components of whole blood initially exiting the body as water, albumin, glucose, oxygen, ammonia, and bilirubin; the latter two substances are filtered out by the hepatocyte cells. As the cells filter, they also produce urea and a negligible amount of bile. A differential equation model has been created for both oxygen and glucose consumption across the reactor using the software Polymath. In order to counteract excessive oxygen consumption by the cells, an internal oxygenator is attached to the packed bed reactor. Following the decision of specific biomaterials best suited for the reactor and attachment to the body, a cost analysis has been conducted. The design satisfies all of the client requirements for treating a patient suffering from acute liver failure.

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