Mid Term Report – IPRO 308

Professor: Dr. Emmanuel Opara

Team Members: Elena Davis, Jennifer Miller, Maje Nazim, Sapna Patel, Shital C. Patel, Yagna Pathak, Venkata Ravuri, Kirthi Reddy, Vidya Shivakumar, Ryan Tanner, Aurimas Vinckevicius

Consultants: Mr. Ray DeBoth

Revised Objectives:

The objective of this Interprofessional Project is to develop an artificial pancreas. This implies a device that will both monitor the blood glucose level and inject insulin to maintain homeostasis. The goal is to achieve both of these in a non-invasive manner.

Among current invasive techniques is venepuncture, which is used to monitor blood glucose levels in patients. Unfortunately, because diabetic patients must constantly monitor their blood sugar level, venepuncture is a very undesirable procedure, as it requires multiple needle punctures a day. It is no surprise that this process is uncomfortable for the patient and therefore a better solution must be developed.

Each sub-group in the IPRO is involved with a different component of the prototype development. While two groups are researching market analysis and the biomechanics of the device, the third group is working on a model prototype for the device. The research topics include determining skin permeability, ionic properties of glucose, iontophoresis for both extraction of interstitial fluid and injection of insulin, role of the C-peptide and the use of electrical impedance as a method of measuring glucose concentration. Through these research groups we mapped out areas, which will help us in developing a non-invasive method. We have decided to use ultrasonic energy and a two-way vacuum system to extract the interstitial fluid and pressure to inject insulin. The glucose concentration will be determined using electrical impedance measurement.

Results to date:

Extraction:

The first step in developing the device is the extraction of interstitial fluid to test the blood-glucose level. The prototype team has reviewed the non-invasive blood glucose monitor model developed by a previous IPRO team and decided to base the glucose monitoring part of the artificial pancreas on this model. Several technologies are being incorporated into the device. Mainly, iontophoresis and ultrasound will be used. The tube to extract fluid is attached to a speaker,which will produce the ultrasound waves to vibrate the skin and open the pores. The vacuum with iontophoresis will be used to extract the interstitial fluid. Iontophoresis will be achieved by coating the speaker with a conductive material and also making a conductive contact between skin and the frame of the speaker. Then an electric potential will be applied to both poles. While in testing phase, the fluid will be stored in a reservoir that can be undone to allow measuring glucose levels in interstitial fluid. Impedance Spectroscopy will be used in the final product to determine the blood glucose level. Impedance spectroscopy measures how changes in the concentration of a given analyte in solution affect the impedance.

Injection:

The second part of the artificial pancreas is insulin injection, which also has to be performed non-invasively. The main idea behind injecting insulin into the body is based on the reversal of the extraction method, which would move the fluid in a different direction. Instead of applying a vacuum to extract the interstitial fluid, pressure will be applied via the same pump through the pressure port. A speaker will be used, again, to create ultrasound in order to open up the pores in the skin. The charges on the speaker will be reversed to produce iontophoresis in the opposite direction and accelerate the diffusion of insulin into the body. A rough pseudocode has been developed that will allow control over the amount and frequency of insulin injections depending on the glucose measurements. By getting frequent blood glucose measurements the insulin pump will be able to provide the necessary amount of insulin on-demand and, thus, keep the blood glucose level as close to normal as possible.

Model:

So far, the prototype team has been working on producing the interstitial fluid extraction part of the artificial pancreas. The model is almost ready for testing to see whether the predictions about the effects of iontophoresis and ultrasound are correct. The model currently consists of a speaker with a small copper tube attached to it. The tube leads to a compartment where the interstitial fluid will be collected. Another tube from the compartment leads to the vacuum port of the pump.

Updated Task Assignments/ Revised Tasks:

The initial groups were divided into biological research, research on market analysis, and prototype design. While the prototype group was provided with information by the other groups they met once every week to develop a model. The research groups were reassigned different tasks as all the relevant information has been obtained. The new groups are customer analysis, final product, and presentation. The customer analysis group is expected to analyze who will use the final product. The group working with final product development will come up with specifications and the overall look of the finished device. The prototype sub-team will continue to work on the model.

1) Final Product (aesthetics) - Vidya, Kirthi, Sapna, Sheetal
2) Patents - Sapna, Kirthi, Venkata
3) Customer Analysis - Jenn, Elena
4) Paper compiling - Kirthi
5) Prototype – Ryan, Yagna, Aurimas, Shital

Obstacles:

The prototype group has run into several design problems. After constructing a very basic prototype of the tissue fluid pump, it was noticed that it is very hard to secure a tight seal between skin and the speaker. Few ideas are being worked on to resolve this issue. Through research, it has been suggested that the injection of insulin may be much more complicated than thought at first. It appears that insulin may clump together forming much larger complexes than the pores in the skin. Few methods have been found that may resolve this issue, such as using a pulse, rather than static current for electrophoresis.